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ENGINEERING OPERATIONS REPORT

Induction Graphitizing Furnace Acceptance Test Report

Nerva
DRA

Project 143

March 1972

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AEROJET NUCLEAR SYSTEMS COMPANY

A DIVISION OF AEROJET-GENERAL

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ENGINEERING OPERATIONS REPORT

Induction Graphitizing Furnace
Acceptance Test Report

Project 143

March 1972

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ABSTRACT

The objective of this report is to document the results of the furnace acceptance test. Evidence of equipment conformance to ANSC Specification AGC 90278A, including ammendments contained in ANSC Purchase Order No. 00136, is given. Testing was completed in accordance to procedures and criteria contained in the ANSC Acceptance Test Plan.

FOREWORD

The induction furnace was designed to meet the requirements of ANSC Specification 90278A, Furnace, Vertical, Vacuum-Inert, Induction. The furnace was designed and constructed by the Cragmet Division of the Cheston Company, Rancocas, New Jersey, An Inductotherm Affiliate, under ANSC Purchase Order N-00136. The Buyer was W. J. Carey. R. P. Radtke, Project Engineer, under the supervision of L. A. Shurley, Manager, Nozzle, Pressure Vessel and Skirt Department, was responsible for design, fabrication, installation and activation of the furnace complex. G. W. Haughton provided Quality Assurance surveillance of the fabrication, installation, and activation. Bldg. 2005 facilities were prepared by A. R. McLain, Plant Engineer. The furnace was procured for the fabrication of the NERVA nozzle extension, Project 143h in Contract SNP-1 with the Space Nuclear Systems Operations. The Project was monitored by G. K. Sievers and K. E. Estes, SNSO-C.

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I. INTRODUCTION

The purpose of this report is to document the results of the furnace acceptance test. This equipment was designed for converting carbon forming substances into graphitic structures according to ANSC Specification 90278A, Furnace, Vertical, Vacuum-Inert, Induction, dated 22 May 1970, shown in Appendix B.

Conformance to the specification was verified by joint effort of ANSC Project Engineering and Quality Assurance. Tests were performed in accordance to procedures and criteria in the ANSC Acceptance Test Plan, shown in Appendix A. Discrepancies were recorded on Inspection Report No's 503993, 503994, and 512330, shown in Appendix C. Disposition of all items was completed and duely documented.

All work and activities referred to herein were performed in accordance with ANSC Purchase Order N-00136, awarded to the Cheston Company on 28 September 1970. The ANSC Acceptance Test Plan operations were completed on 24 August 1971.

The Furnace System was accepted by NERVA Engineering Operations, Project 143, on August 30, 1971.

II. SUMMARY

The induction furnace was designed to provide the controlled temperature and environment required for the post-cure, carbonization and graphitization processes for the fabrication of a fibrous graphite NERVA nozzle extension. The furnace is capable of automatically controlled temperature rise rates of 5 to 60°C/hr from 120 to 2750°C. The furnace atmosphere is controllable at 10^{-2} mm Hg vacuum to 3 psig nitrogen or argon to 2000°C, and 0 to 3 psig argon to 2750°C. The hot zone dimensions are 11 feet mean diameter and 14 feet long. The length may be extended to 19 feet by redesign of the work load support.

The acceptance testing required six tests and a total operating time of 298 hours. Low Temperature Mode Operations, i.e., 120 to 850°C, were completed in one test run. High Temperature Mode Operations, i.e., 120 to 2750°C, were completed during five tests. The test procedure was contained in the ANSC Acceptance Test Plan. This plan was prepared to demonstrate all performance requirements contained in Section 3 of the furnace specification No. AGC 90278A.

All test data was recorded by Quality Assurance Representatives in the Quality Assurance Log Book. Satisfactory completion of the Acceptance Test Plan was certified by the supplier, and verified by ANSC Quality Assurance. Discrepancies were reported on Inspection Report No's 503993, 503994, and 512330. Satisfactory dispostion of all items was completed.

A summary of the furnace performance as compared to specification requirements is shown in Table 1. The performance demonstrated met or exceeded the specification requirements except for the furnace shell temperature. The outer chamber flange temperature reached 85°C at the maximum hot zone temperature of 2695°C. However, the high surface temperature was acceptable since it was within the safe limit of 116°C. This limit was established by the maximum flange O-ring use temperature.

Satisfactory completion of the ANSC Acceptance Test Plan demonstrated that the induction furnace system meets the requirements of ANSC Specification AGC 90278A. The equipment has been accepted by Project Engineering as operational.

TABLE I

Summary
of
Acceptance Test Performance of Induction Furnace

Specification Requirement			Furnace Performance
Section 3.0			
Para No.			
1.1	Maximum Temperature, 2750°C		2695°C, within controllability range of ± 55°C.
1.2	Temperature Controllability		
	1.2.1	± 5°C at 120°C to 850°C	± 5°C at 120°C and 700°C.
	1.2.2	± 2% at 850°C to 2750°C	Less than ± 1% at 700°C and 2695°C.
1.3	Temperature Gradient, 100°C maximum at 2750°C		10°C at 2695°C.
1.4	Temperature Rate Controllability		
	1.4.1	5 to 15°C/hr at 120°C to 850°C	5°C/hr at 120 to 240°C and 15°C/hr at 600°C to 850°C
	1.4.2	15 to 60°C/hr at 120°C to 2600°C; 15° to 60°C/hr at 2600°C to 1500°C	60°C/hr at 2180°C to 2600°C; 15°C/hr at 2695 to 2680; 60°C/hr
2.1	Furnace Atmosphere		
	2.1.1	Vacuum, 50 microns, maximum	17 microns
	2.1.2	Argon or nitrogen 0.1-3.0 SCFM 50 microns - 3 psig	Argon and nitrogen, less than 1 ppm H_2O. 0.1-10 SCFM to 3.0 psig.
2.2	Rate of Evacuation, ambient to 50 microns in 30 minutes, maximum		Ambient to 50 microns in 25 minutes.

Summary of Acceptance Test Performance of Induction Furnace (cont'd)

Section 3.0 Para No.	Specification Requirement	Furnace Performance
2.3	Rate of Back-Fill, 50 microns to ambient in 20 minutes, maximum	Air, 15 minutes; N_2 or Ar, 10 minutes.
2.4	Inert Gas Pressure Control, 5 to 30 in. Hg	Manual gas pressure control at 3.0 psig.
2.5	Forced Gas Convective Cooling, 2750°C to 200°C in seven days at 60°C/hr, maximum	2695°C to 200°C in two days at 60°C/hr, maximum.
3.1	Chamber Leak Rate, 1×10^{-4} mm Hg/min pressure rise at 75 microns	1×10^{-6} mm Hg/min at 75 microns.
3.2	Water Channel Leak Rate, no leaks at 100 psig	No leaks at 100 psig.
4.3	Water Temperature, 70°C maximum	61°C, chamber water outlet.
4.5	Furnace Shell Temperature, 50°C maximum	85°C (flanges).

III. DISCUSSION OF RESULTS

A. GENERAL

Data and observations during the acceptance testing were recorded by Quality Assurance representatives in the Quality Assurance Log Book. Special test equipment included contact pyrometers, optical pyrometers, and bulb thermometers, for temperature measurements. Precision levels and steel tapes were used to measure internal furnace dimensions. Temperature measurement equipment carried current AGC calibration certification numbers.

B. MEANS OF EQUIPMENT PERFORMANCE EVALUATION

The test operation defined by the Acceptance Test Plan was designed to demonstrate furnace performance requirements of ANSC Specification 90278A, Appendix B. Completion of operations activity items was certified by the supplier and satisfactory demonstration to meet the test criteria was verified by the ANSC Quality Assurance Representative. Signatures were affixed to the Acceptance Test Plan.

Furnace operations required by the ANSC Acceptance Test Plan, Appendix A, were performed from 24 July to 24 August 1971. The plan consisted of four sections: Mechanical, Electrical, Safety Interlock, and Performance Operations. The Performance Operations were completed in two phases: Low Temperature Mode, and High Temperature Mode.

The Low Temperature Mode required one furnace run to satisfy the requirements of the acceptance test plan. Five tests were required to complete the High Temperature Mode operations. Prior to performance tests, a run to 2000°C was completed to outgas volatiles, such as water vapor, sulfur, and metal impurities, from the graphite components within the furnace hot zone. Table 2 lists the test schedule and operating durations. The acceptance testing required 298 hours of operation.

Discrepancies were recorded on Inspection Report No's 503993, 503994, and 512330, Appendix C. Disposition of all items was completed by Project Engineering. The furnace system was accepted by NERVA Engineering Operations, Project 143, on August 30, 1971.

TABLE 2

Section IV
Acceptance Test Schedule
(July-August 1971)

Test No.	Mode	Dates	Duration
1	High Temperature	7/24 thru 7/26	52 hours
2	Low Temperature	7/29 thru 8/1	56 hours
3	High Temperature	8/3 thru 8/6	69 hours
4	High Temperature	8/7 thru 8/8	37 hours
5	High Temperature	8/11 thru 8/13	52 hours
6	High Temperature	8/23 thru 8/24	32 hours

The following paragraphs summarize the test results as required per Section 3.1 of Specification AGC 90278B.

C. COMPLIANCE WITH EQUIPMENT SPECIFICATIONS

"Section 3 REQUIREMENTS

3.1 Performance. -

3.1.1 Functional Characteristics. -

The furnace shall be capable of heating the graphite work load to the maximum operating temperature with the performance requirements described below. The work load shall be as defined in Table I and Figures 1 and 2. The furnace shall be capable of achieving the following performance.

3.1.1.1 Temperature Capability. -

3.1.1.1.1 Maximum Temperature. -

(a) The furnace shall be capable of operating at a maximum continuous operating temperature of 2200°C, within the useful life requirements of 3.1.2.2.

(b) Option 1 - High Temperature Capability. - The furnace shall be capable of operating at a maximum continuous operating temperature of 2750°C within the useful life requirements of 3.1.2.2."

The required maximum continuous operating temperature of the furnace was 2750°C, Option 1, above. The controllability requirements, Para. 3.1.1.1.2 below, was plus-minus 55°C. Therefore, a maximum controlled temperature within the range of 2695°C to 2750°C was acceptable.

The maximum furnace temperature was demonstrated in accordance with Test No. A.1.e, Section IV of the Acceptance Test Plan. The maximum furnace temperature, as measured with an L and N optical pyrometer, was 2555°C. A temperature correction, accounting for stem and radiation losses, was required to compute the difference between the true susceptor temperature and optical pyrometer target temperature readout. (The target was a closed-end graphite tube

extending 8 cm into the hot zone from a side sight port.) An oversight or omission of such correction can result in operations at over-design conditions.

The temperature difference was calculated to be 105°C. The analytical thermal model is described in Appendix D. The correction for absorption of radiation by the quartz glass window was 35°C. The total temperature correction was 140°C. Therefore, the maximum corrected furnace temperature attained was 2555°C plus 140°C, or 2695°C. This value satisfied the requirement for maximum controllable furnace temperature.

"3.1.1.1.2 <u>Temperature Controllability.</u> -

> (a) The furnace temperature shall be controllable within ± 2% of any set point, set between 850°C and the maximum operating temperature.
>
> (b) <u>Option 2 - Low Temperature Control Capability.</u> - The furnace temperature shall be controllable within ± 5°C of any set point, set between 120°C and 850°C. The temperature will be measured on the work load when enclosed within a retort, to be supplied by ANSC."

The temperature controllability requirement in Para (a) of ± 2% was met at 700°C and at 2695°C. The test procedure was given in Para. A.1.a and Para A.1.e of the Acceptance Test Plan. The temperature of 700°C was met in lieu of 850°C because the programed cam controller was inadvertently set at 700°C. This deviation in procedure was reported in Quality Assurance Inspection Report No. 503993, Item 5, and approved by Project Engineering. The lower (700°C vs 850°C) temperature controllability was more difficult because it required greater instrumentation sensitivity.

The range for ± 2% at 700°C is ± 14°C, and 2750°C (maximum attainable temperature) is ± 55°C. The controllability attained at 700°C and 2695°C was ± 5°C. This was within the operators ability to read the temperature print-out. Therefore, the furnace system was well within the temperature controllability requirement of the specification.

The low temperature control capability requirement of ± 5°C, Para. (b) above, was demonstrated at 120°C, as defined by Para A.2.a of the Test Plan. The range of temperature control at 120°C was ± 5°C; thus, the requirement of the specification was met.

> "3.1.1.1.3 Temperature Gradient. - The axial temperature gradient shall be within 100°C over the length of the susceptor corresponding to position of the work load when the furnace is operating at the maximum temperature capability."

The axial temperature gradient was determined during Test A.1.f of the Test Plan. The furnace temperatures at the top and bottom viewports were measured. The measurements were 2555°C on top, and 2545°C at the bottom. The temperature correction of 140°C gave a 10°C axial temperature difference, 2695°C minus 2685°C. Therefore, the axial temperature difference of 10°C at the maximum operating temperature satisfied the specification requirement with a 90°C positive margin.

> "3.1.1.1.4 Temperature Rate Controllability. -
>
> The rate of temperature increase shall be controlled at 15 to 60°C per hours between 120°C and 2600°C. The rate of temperature increase shall be no less than 60°C per hour between 2545°C and 2600°C. The rate of temperature decrease shall be controllable at 15 to 60°C per hour between the maximum operating temperature and 1500°C.
>
> (b) Option 2 - Low Temperature Control Capability. - The rate of temperature increase shall be controllable at 5 to 15°C per hour between 120°C and 850°C."

The specification required the rate of temperature rise and decrease to be controllable within defined rate and temperature ranges. The procedures established in the Acceptance Test Plan provided demonstration of the lowest and highest required temperature rates. In general, it is more difficult to demonstrate low heating rates at low temperatures, and high heating rates at high temperatures.

The Acceptance Test Plan, Section IV, High Temperature Mode, Paragraphs A.1.a, A.1.c, and A.1.g required 15°C/hr from 120°C to 240°C, 60°C/hr from 2180°C to 2600°C, and 15°C/hr from 2750°C to 2680°C, and 60°C/hr from 2680°C to 1800°C. Low temperature control testing was completed with a stainless steel retort positioned within the furnace. Paragraph A.2.b defined the low temperature mode test procedure. Heating rates of 5°C/hr from 120°C to 160°C, and 15°C/hr from 600°C to 850°C were required.

The required temperature rates were satisfactorily demonstrated. The High Temperature Mode tests were completed during four furnace runs. All low temperature control tests were successfully completed during a single test. Some difficulty was encountered in meeting the required heating rates because the program cams were not accurately prepared by the supplier. However, the heating rates demonstrated were the rates programed on the cams. A Quality Assurance Inspection Report documented the temperature rate deviations.

Inspection Report No. 503993, Items 5 and 8, identify temperature rate deviations from the rates required by the Acceptance Test Plan. In each case, the furnace temperature followed the programed temperature demanded by the cam. This demonstrated that the furnace was controllable with the accuracy required. Future operation will require more accurately cut cams to achieve the rates desired.

"3.1.1.2 <u>Furnace Atmosphere.</u> -

3.1.1.2.1 <u>Atmospheric Conditions.</u> - The temperature controllability and profile, shall be maintainable with each of the following furnace atmospheres:

(a) Vacuum — 50 microns, maximum

(b) Argon or nitrogen

(1) Flow Rate — 0.1 - 3.0 SCFM
(2) Pressure — 50 microns - 3 psig

Vacuum will not be required at temperatures which cause sublimation of carbon."

The furnace atmosphere control system was demonstrated during the acceptance testing. Pressure and flow control was shown at all temperatures and temperature rates. Vacuum was held to less than 50 microns at 400°C and 2000°C. The ultimate vacuum attained was 17 microns at ambient temperature.

Argon and nitrogen flow rates were controllable at 0.1 to 10 SCFM, which is within the 0.1 to 3 SCFM requirement. Inert gas pressure was maintained at 3.0 PSIG during all testing. The inert gas dew point was less than 1 ppm.

> "3.1.1.2.2 Rate of Evacuation. - The cold furnace shall be capable of being evacuated of air at ambient conditions to 50 microns in 30 minutes, and being held continuously for a minimum period of fourteen days."

A 50 micron vacuum was attained within 30 minutes, as required by the specification. The shortest pumpdown time was 25 minutes. The procedure for this test was given in Paragraph B.1.a of the Acceptance Test Plan, Section IV.

Regarding 14 days at 50 microns operations - no maintenance required was demonstrated for 14 cumulative days of operations, as opposed to continuous - the later being not practical to execute during Acceptance Tests.

> "3.1.1.2.3 Rate of Back-Fill. - The cold furnace shall be capable of being back-filled with air, nitrogen, or argon from fifty microns to ambient pressure in a maximum of twenty minutes."

The rate of back-fill with air was determined to be 50 microns to ambient pressure in 15 minutes. Paragraph B.1.b of the Acceptance Test Plan, Section IV, required back-fill within 20 minutes. Since the inert gas supply is pressurized, back-fill times with argon and nitrogen were less than 15 minutes.

> "3.1.1.2.4 Option No. 3, Inert Gas Pressure Control. - The shell pressure shall be controllable at 5 to 30 inches of Hg with argon or nitrogen flowing at two SCFM."

Both argon and nitrogen gas pressures were controlled and recorded during the Acceptance Testing at 3.0 psig as required by Section IV, Paragraphs A.1 and A.2. The flow rate of 3 SCFM was maintained at 3 psig pressure. This test was sufficient to determine acceptability of the inert gas control system at all required pressures and flows.

"3.1.1.2.5 <u>Option No. 4, Forced Gas Convective Cooling.</u> - The inert gas system shall provide convective cooling sufficient to cool the furnace from 2750°C to 200°C in seven (7) days at a rate not to exceed 60°C in one (1) hour.

"3.1.1.2.5.1 <u>Option 4, Forced Gas Convective Cooling.</u> - Inert gas shall be circulated through the furnace hot zone to provide convective cooling at temperatures between 800°C and 120°C."

The forced gas convective cooling system provided a marked increase in cooling rates at temperatures below 800°C. The system consisted of a high temperature blower which circulated hot furnace gases through a gas-water heat exchanger.

The performance of this system satisfied the requirements of the specification. Using the procedure of the Acceptance Test Plan, Section IV, Paragraph A.1.h, a two-day cooldown time was demonstrated. When cooling rates up to 200°C/hr were employed, the total cooldown time from 2695°C to 200°C was less than one day. The furnace test was significantly better than required by the specification.

"3.1.1.3 <u>Leak Rates.</u> -

"3.1.1.3.1 <u>Furnace Shell.</u> - The maximum allowable gas leak rate of the furnace shell shall be 1 x 10^{-4} mm Hg per minute pressure rise when the vacuum system is isolated from the shell, and the pressure within the shell is 75 microns.

"3.1.1.3.2 <u>Cooling Water Channels.</u> - All cooling water channels, including those for the furnace shell, if the ASME Boiler and Pressure Vessel Code is applicable, induction coil, vacuum system, and supply and outlet lines, shall not leak any water when tested at 100 psig."

The furnace shell gas and water channel leak rates were tested during the furnace installation and activation periods according to procedures established in the Acceptance Test Plan and Specification.

The furnace shell gas leak rate was tested as required by Paragraph C.1 of the Acceptance Test Plan, Section IV. The plan referenced Paragraph 4.2.1 of the Specification. The measured shell leak rate was less than 1×10^{-6} mm Hg/min pressure rise at 75 microns. The leak rate test result met the specified rate of 1×10^{-4} mm Hg/min, maximum with 10^{-2} mm Hg/min margin.

The integrity of the furnace system coolant channels was demonstrated prior to the first elevated temperature test. The procedure was given in Paragraph 1.2 of the Acceptance Test Plan, Section I. No leaks were visually detected.

During the elevated temperature testing, the test procedure in Paragraph C.4, Section IV, was used. Several leaks were noted and recorded in Inspection Report No. 503993, Items 12 and 18. Item 12 identified water leaks in air release valves on the furnace jacket. The valves were added to the system as a field modification. Release of entrapped air at the top of the jacket allowed increased cooling of the top flange. However, when first installed, the valves leaked water. After the supplier repaired the valves, no leaks were visually detected.

Item 18 describes water leaks observed in the Baltimore Air Coil water cooling tower. The cause of the leaking was determined to be excessive turbulance in the water sump. As a result, water flowed through the fan section to the ground below. The supplier placed baffles in the sump which reduced the turbulance, and prevented all leakage.

"3.1.1.4 Furnace Water Cooling. -

"3.1.1.4.1 Capacity. - The cooling water system shall be supplied by the contractor and shall have a capacity sufficient to provide coolant for the induction coil, furnace shell, and vacuum pump as required to meet the requirements of this specification."

The capacity of the cooling water system was selected by the supplier to meet the requirements of the system, and the maximum water outlet temperatures required by the specification. The system selected delivered approximately 360 GPM at 60 psig. The Baltimore Air Coil cooling tower removed up to 85,000 BTU/hr from the recirculating coolant.

Acceptance tests which verified the adequacy of the cooling water system are given below.

> "3.1.1.4.2 <u>Backup System.</u> - The cooling system shall be capable of providing for an automatic alternate coolant supply in the vent of major component or electrical power failure."

The automatic alternated coolant supply was provided by ANSC. Functionally, the system was shown to provide cooling water in excess of 400 GPM at 60 psig inlet pressure. The test procedure was given in Paragraphs I.3 and I.4 of the Acceptance Test Report, Section I.

The emergency water backup to the normal closed-loop cooling system performed satisfactorily. In the event of a plant power outage, the furnace power would automatically shut off; and, the emergency water supply would safely cool the furnace to ambient temperature.

> "3.1.1.4.3 <u>Water Temperature.</u> - The cooling water shall not exceed 70°C at the induction coil and furnace shell outlets when the heating zone is operated continuously at the maximum operating temperature."

The cooling water temperatures were tested according to the procedure listed in Paragraph D.1 of the Acceptance Test Plan, Section IV. The maximum water temperatures measured while the furnace was operating at 2695°C were as follows:

Main Water Inlet	32°C
Main Water Outlet	52°C
Main Water - ΔT	20°C
Induction Coil	58°C
Power Supply	61°C
Furnace Shell	61°C

In particular, the maximum induction coil and furnace shell water temperatures were 58°C and 61°C, respectively. These test results were within the specification requirement of 70°C.

> "3.1.1.4.4 Water Flow. - All coolant channels shall be protected from blockage by particulate matter (greater than 0.05 inch diameter)."

Both the closed-loop cooling system and emergency water cooling supply have screens which trap all particulate matter greater than 0.05 inch in diameter. When all testing was completed, the screens were checked. No particulate matter was observed.

> "3.1.1.4.5 Furnace Shell Cooling. - The outside wall temperature of the furnace shell, including all attached fittings, shall not exceed 50°C when operating continuously at the maximum operating temperature."

The outside wall temperature of the furnace shell was measured at numerous locations during the acceptance testing according to procedures given in Paragraph D.2 of the Acceptance Test Plan, Section IV. The shell flange temperatures exceeded the specification limit of 50° at furnace temperatures in excess of about 1900°C. At 2695°C, the maximum flange temperature was 85°C.

Accordingly, the discrepancy was noted as Item 6 on Inspection Report No. 503993. Final disposition to accept the overtemperature was made. The temperature design limit was found to be 116°C, the maximum O-ring use temperature. Therefore, the 85°C temperature was technically acceptable.

> "3.1.2 Operability. - The furnace system shall be capable of being operated within the following requirements.
>
> "3.1.2.1 Maintainability. - No periodic maintenance shall be required within a time period of fourteen days while the furnace is being operated according to the performance requirements of Section 3.1.
>
> "3.1.2.1.1 Maintenance and Repair Cycles. - There shall be no periodic maintenance required on the induction coil or furnace shell.
>
> "3.1.2.1.2 Service and Accessibility. - All components of the furnace which require periodic maintenance shall be accessible for repair. Required ladders, staircases, and platforms shall be provided by the contractor."

The operability requirements of the specification were tested using the procedures in Paragraph E.1 of the Acceptance Test Plan, Section IV. No periodic maintenance was required on any furnace component during fourteen days of operation except for the need to add rust inhibitor to the water supply.

Due to rust in the cooling water, it was necessary to add a chromate rust inhibitor. This maintenance was listed as a discrepancy, and reported as Item 19 of Inspection Report 503993. However, the disposition was to accept this action, since anti-rust water treatement is considered normal maintenance.

> "3.1.2.2 Useful Life. - The furnace system will have a minimum useful life of eight years, allocated as follows:
>
> Rated Operating Life
>
> (a) Time 5000 hours, minimum
> (b) Thermal Cycles 50, maximum
>
> A thermal cycle shall conform to the performance requirements in Section 3.1, and a maximum hold time of five hours at or below the maximum operating temperature."

The useful life requirement was tested in compliance to procedures established by Paragraph E.2 of the Acceptance Test Plan, Section IV. The total operating time of the furnace system was 298 hours. No significant deterioration of the furnace components was visible after testing was completed.

The useful ife of 5000 hours is a design requirement, introduced for the purpose of influencing the design, but it was not expected and not practical to be demonstrated during Acceptance Testing.

D. OTHER REQUIREMENTS

Other requirements, as related to conformance drawings, materials, functionality of safety interlocks, were demonstrated prior to shipment from the manufacturing site or during the Acceptance Testing after installation. Verification of functionality of all items not covered within the Specification Requirements, Section 3.1, can be found in the appropriate sections of Appendix A.

IV. CONCLUSIONS

1. The performance requirements of ANSC Specification No. AGC-90278A, Section 3, were satisfactorily demonstrated using procedures according to the ANSC Acceptance Test Plan.

2. The furnace chamber flange temperature exceeded the maximum temperature limit. However, the higher temperature was acceptable because it was within the safe operating limit.

3. The largest 2750°C induction furnace in the free world is operational.

V. RECOMMENDATIONS

1. The induction furnace should be operated prior to expiration of supplier's guarantee on 25 August 1972.

2. Precautions should be taken when loading or unloading the furnace to prevent damage to the susceptor or work load support.

3. Inspect the Baltimore Air Coil water cooling tower to determine the cause of the 9 psig pressure drop which is in excess of that specified in the supplier's manual.

4. The existing Tungsten Rhenium thermocouples should be replaced with a heavy duty type.

5. Prior to future operation, conduct a water flow distribution check. Monitor all cooling circuits during subsequent operation.

APPENDIX A

ANSC INDUCTION GRAPHITIZING FURNACE

ACCEPTANCE TEST PLAN AND PROCEDURES

INDUCTION GRAPHITIZING FURNACE

ACCEPTANCE TEST PLAN AND PROCEDURES

ANSC PURCHASE ORDER N-00136

CRAGMET DIVISION OF CHESTON CORPORATION

RANCOCAS, NEW JERSEY

REVISION "A"

PROCEDURAL AMENDMENT

TO

INDUCTION FURNACE OPERATIONS

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APPLICABLE DOCUMENTS

1. AGC SPECIFICATION 90278A, FURNACE, VACUUM - INERT,INDUCTION

2. ANSC PURCHASE ORDER, VER. VACUUM - INERT ATMOSPHERE INDUCTION FURNACE, AND AMENDMENTS TO AGC SPECIFICATION 90278A.

3. CRAGMET DRAWINGS, FURNACE, VACUUM - INERT INDUCTION, NOS. 3086-100-00B THROUGH 3086-914-10B.

4. ANSC DRAWINGS, FACILITY PREPARATION FOR GRAPHITIZING FURNACE, NOS. NPE 30-1-70A THROUGH NPE 12-1-71.

ACCEPTANCE TEST PLAN

SECTION I - MECHANICAL OPERATION

SECTION II - ELECTRICAL OPERATION

SECTION III - SAFETY INTERLOCKS

SECTION IV - PERFORMANCE

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ACCEPTANCE TEST PLAN

TEST	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
ll Tests	-			1. Determine that operating procedures performed during acceptance testing conform to the Operating Manual.	1a. The operating procedures in the Operating Manual will be followed for all operations.	LOG BOOK	[illegible signature]	
					1b. Observe and record any deviation from procedures given in the Operating Manual, except for special procedures given in Operations below.	LOG BOOK	[illegible signature]	

ACCEPTANCE TEST PLAN
SECTION I. MECHANICAL OPERATIONS

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
A. Work Load Support	3.3.1.4	3086-200-60A		1. Work load support is within ± one inch, axially and diametrically after each thermal cycle.	1. Using the chamber flange for reference, measure and record level of top surface of work load support before and after each cycle using special gaging, No. 3086.	LOG PG. 146	[illegible]	[illegible] 7-8 thru 9-23
				2. Work load support will carry 9600 lbs without structural failure.	2. Position a 9600 lb simulated work load on the hot end support. Observe and record appearance of support after test using special gaging No. 3086.	LOG PG 146	[illegible]	[illegible] 7-14-71
B. Susceptor	Letter Agreement	3086-200-20A		1. Inscribed circle of the susceptor I.D. is 11 feet minimum extending as a right circular cylinder for its full length.	1. Measure and record the inside perpendicular diameter of the susceptor at the top, middle, and bottom of the susceptor. Obtain dimensions at three equally spaced locations on the circumference. Use special gaging No. 3086.	LOG PAGES 143-146, 128 281	[illegible]	D.W. [illegible] 7-11-71 6-25-71
				2. Maintain history of susceptor movement before and after thermal cycles. Amount of movement allowable: (TBD).	2. Repeat Step 1 above before and after each thermal cycle. In addition, measure the height and level of the susceptor's top surface in three equally spaced places on the circumference.	LOG PAGES 227, 170, 143	[illegible]	D.W. [illegible] 6-2-71 6-25-71
C. Induction Heating Coil	3.3.1.6.2	3086-490-10H		1. Coil centerline is held within ± 1 inch of the furnace shell centerline.	1. Measure and record coil position relative to shell centerline before and after each thermal cycle.	LOG PAGE 127	[illegible]	[illegible] 6-2-71
D. Thermal Insulation	3.3.1.13.1	3086-200-10A		1. Determine the graphite felt insulation thickness and the lot to lot location.	1. Observe, measure and record the material thickness at 4 elevations and the location of each lot of material used.	LOG PAGES 149, 99, 127	[illegible]	[illegible]
	3.3.1.13.2			2. Fiberglas liner completely covers the	2. Observe and record appearance of			

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
Furnace Shell	3.3.1.7.5	3086-200-10A		1. Spring-loaded furnace lid releases internal pressure when greater than 3.0 psig.	1a. Raise chamber pressure to 3.5 psig and verify activation of lid relief mechanism.	LOG PAGE 145	[illegible]	[illegible] 7/12/71
					1b. Observe and record pressure which first activates lid relief.		[illegible]	
	3.3.1.4.1	3086-200-60A		2. Open heat sink elevation corresponds to reading on control panel meter.	2. Open heat sink and measure and record height of heat sink at the five positions of the panel meter, No. 10-	LOG PAGE 135	[illegible]	[illegible] 7-10-71
				3. Heat sink reseats during cycling. Criteria to be determined during test.	3. Observe heat sink seating upon closure. Technique TBD during test.	LOG PAGE 141	[illegible]	[illegible] 7/12/71
Vacuum System		3086-100-44 3086-600-20		1. Oil in four mechanical pumps and the "Roots" type blower is at the level required by the manufacturer. Level required shown on pump indicator.	1. Observe that the oil level is at the level required on sight-through windows of four mechanical pumps, Nos. 20-1, and the "Roots" type blower, No. 44-1.	LOG PAGE 90	[illegible]	[illegible] 6-21-71
		3086-600-10		2. Air pressure supply is 80 psig minimum to pressure regulator.	2. Observe and record air pressure on gauge No. 10-1.	LOG PAGES 135-136	[illegible]	[illegible] 7/12/71
		3086-600-10		3. Regulated air pressure to main vaccum valve is 35 psig.	3. Observe and record regulated air pressure on gauge No. 10-1 for main vacuum valve 10-2.	LOG PAGE 136	[illegible]	[illegible] 7/12/71
		3086-100-50 3086-600-20		4. The vacuum capability of each of four mechanical pumps is 10μ (manufacturer's certification).	4a. Close manual vacuum valves Nos. 50-2.	LOG PAGES 137 [illegible]	[illegible]	[illegible] 7/12/71
					4b. Turn on each vacuum pump No. 20-1.			
					4c. Measure and record the downstream pressure with the No. 20-13 vacuum gauge.		[illegible]	
		3086-100-44 3086-100-50 3086-600-20C		5. Main vacuum valve is fully closed after five cycles. No further chamber pressure drop detected.	5a. Turn on four mechanical vacuum pumps (20-11) and reduce furnace pressure to 100μ.	LOG PAGE 149	[illegible]	[illegible] 7-14-71
					5b. Open two manual valves. Nos. 50-2.		[illegible]	
					5c. Turn on "Roots" type blower, No. 44-1.		[illegible]	
					5d. Open and close main vacuum valve No. 20-4 five times in immediate sequence.		[illegible]	
					5e. Observe and record any change in chamber pressure on gauge No. 20-23 every 5 min.		[illegible]	

ACCEPTANCE TEST PLAN - SECTION I - MECHANICAL OPERATIONS

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFIC BY A
G. Inert Gas Flow Control System		3086-600-20C NPE-30-6-70A		1. Argon gas supply pressure is 150 psig minimum.	1a. Close valve Nos. 20-8, 20-9, and 20-15.	LOG PAGE 126	[illegible]	[illegible]
					1b. Observe and record inert gas pressure on gauge 70-26.		[illegible]	
				2. Nitrogen gas supply pressure is 150 psig minimum.	2. Repeat Item 1 above.	LOG PAGE 126	[illegible]	[illegible]
				3. Emergency Argon gas supply pressure is 200 psig minimum.	3. Repeat Item 1 above.		[illegible]	
				4. Dew point of argon gas supply is less than -40°F.	4. Measure dew point of inert gas with Beckman Trace Moisture Analyzer, Model 340 (ANSC supplied).	LOG PAGE 145	[illegible]	[illegible]
				5. Dew point of nitrogen gas is less than -40°F.	5. Repeat Item 4 above.		[illegible]	
		3086-600-20C		6. Argon gas flow and pressure in the furnace shell is controllable at 3.0 psig and 3.0 SCFM.	6a. Prepare furnace for inert gas operation.	LOG PAGE 145	[illegible]	[illegible]
					6b. Open furnace relief valve No. 20-2 and valves Nos. 20-8 and 20-15.		[illegible]	
					6c. Manually adjust flow, as measured on flowmeter No. 20-5, to 3 SCFM with valve 20-8.		[illegible]	
					6d. Manually adjust pressure to 3 psig, as measured on gauge No. TBD, with relief valve No. 20-2.		[illegible]	
					6e. Repeat 6c and 6d as required to flow 3.0 SCFM at a 3.0 psig.		[illegible]	
		3086-300-20		7. Argon gas is detected flowing into each of three sight ports.	7a. Open each of three valve Nos. 600-20-7 at sight ports Nos. 300-20.	LOG PAGE 147	[illegible]	[illegible]
					7b. Detect gas flow by removing gas supply line and feeding gas stream.		[illegible]	
H. Power Supply and Controls				No mechanical tests required.				
I. Cooling Water (Note: All pressure reducers are to be adjusted during heat-up to thermally balance system)		NPE 30-5-70A 3086-600-30B 3086-100-90		1. Normal water pump No. 30-3 turns on automatically.	1a. Close valve No. 70A-V-1.	LOG PAGE 122 [illegible]	[illegible]	[illegible]
					1b. Open valves Nos. 30-9, -11, -12, -13, -14 (40 valves to open).		[illegible]	
					1c. Turn on power to normal water pump No. 30-3.		[illegible]	
					1d. Open valves No. 70A-V-4 and 30-15 to fill closed loop water system with domestic water.		[illegible]	

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ACCEPTANCE TEST PLAN - SECTION I - MECHANICAL OPERATIONS

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
					1e. Observe that normal pump No. 30-3 turned on when the water level in the hot well, No. 100-90, filled to the lower limit of level indicator switch No. 30-23.	LOG PAGES 122-123	[illegible]	[illegible] 7/1/71
					1f. Shut-off valves Nos. 70A-V-4, and -5, and valve No. 30-15.		[illegible]	
					1g. Record water pressure at pump outlet, as measured on gauge No. 30-29, and pressure at gauge No. 70A-9 (PI-5 and -6)	GAUGE BROKEN	[illegible]	[illegible]
		3086-600-30B		2. No leaks in water system (3086-600-30B) that can be visually observed.	2. Observe and record locations of any water leak visually detected in system.		[illegible]	
		NPE 30-5-70A 3086-100-90 3086-600-30B		3. Emergency water pump turns on automatically and emergency water supply activates during a simulated power outage.	3a. Turn on normal water pump No. 30-3.		[illegible]	
					3b. Open valves Nos. 70A-V-1 and -2, and -6.	LOG PAGE 123	[illegible]	[illegible] 7/1/71
					3c. Turn off normal water pump to simulate power outage.		[illegible]	
					3d. Adjust No. 70A-PRV-1 pressure regulator to activate valve No. 70A-ECV-1 at first drop in system pressure.		[illegible]	
					3e. Repeat 3b, 3c and 3d, as required to properly adjust PRV-1.		[illegible]	
					3f. Observe the emergency water pump No.30-3 start up when the water level in the hot well reaches the upper limit of level indicator switch, No. 30-23.		[illegible]	
					3g. Measure and record emergency pump outlet pressure at gauge No. TBD, for information only.		[illegible]	
				4. Emergency water supply shuts off automatically during a simulated return to normal electric power.	4a. Turn on normal water pump to simulate return to normal power.	LOG PAGES 123, 114	[illegible]	[illegible] 7-1-71
					4b. Observe that emergency water supply shuts off automatically.		[illegible]	
		3086-500-30		5. BAC cooling tower operates with no visible water leakage.	5a. Turn on fan motors and water circulating pump motor.		[illegible]	[illegible] 7/23/71
					5b. Observe and record any visible water leaks.		[illegible]	
					5c. Record water pressure on gauges, Nos. TBD for information only.		[illegible]	

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ACCEPTANCE TEST PLAN - SECTION I - MECHANICAL OPERATIONS

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
		3086-600-30B		6. Cooling water flows through mechanical vacuum pumps Nos. 30B-VP-1, -2, -3, and -4; and No. 30B-BL.	6a. Observe water flow from each of five pumps Nos. 30-VP-1, 30-VP-2, 30-VP-3, 30-VP-4, and 30-BL.	LOG PAGE 122	[illegible]	[illegible] G.W. Haught 7-16
					6b. Measure and cored flow rate for information only.		[illegible]	
				7. Cooling water flows through each of three coil sections.	7a. Observe water flow at line sight glasses Nos. 30-20 in 11 places. Impeller blades are not distinguishable.		[illegible]	G.W. Haught 7-
					7b. Measure and record water flow rate.		[illegible]	
		3086-600-30B		8. Cooling water flows through the bottom shell section.	8a. Observe water flow from bottom shell section.		[illegible]	G.W. Haught 7-16
					8b. Measure and record flow rate for information only.		[illegible]	
		3086-600-30B		9. Water flows through the middle shell section.	9a. Observe water flow from middle shell section.		[illegible]	
					9b. Measure and record flow rate for information only.		[illegible]	
		3086-600-30B		10. Water flows through the top shell section.	10a. Observe water flow from top shell section.		[illegible]	G.W. Haught 7-
					10b. Measure and record flow for information only.		[illegible]	
		3086-600-30B		11. Water flows through the power supply components.	11a. Observe flow from power supply.		[illegible]	
					11b. Measure and record for information only.		[illegible]	G.W. Haught 7-
). Instrumentation, Controls, and Control Cubicle				No mechanical testing required.				

ACCEPTANCE TEST PLAN
SECTION II. ELECTRICAL OPERATION

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
All Components	4.4.1(b)			1. The following criteria applies to all component tests: No electrical malfunctions, including short circuits, fuse burn-out, breaker disconnect, or other electrical failure.	1. All electrical components shall be demonstrated to perform properly.	—	[signature]	R.F. Pandlk 7/23/71
A. Work Load Support				No electrical test required.				
B. Susceptor				1. See Section IV.	1. See Section IV.			
C. Induction Heating Coil	3.3.1.6.3	3086-490-10G		1. The coil is electrically insulated. No arcing permitted.	1. High voltage test per Inductotherm Test Procedure No. 10G-A-3948.	LOG PAGES 126, 97	[signature]	[signature] 7-8-71
					1a. Connect induction coil to 5000 VDC voltage supply. Verify connection.			
					1b. Probe entire coil surface with ground wire.		[signature]	
					1c. Detect by sight and sound arcing through electrical insulation on coil.		[signature]	
					1d. Record location of arc and immediately notify ANSC and Cragmet Project Managers.		[signature]	
D. Thermal Insulation	3.2.2.1(d)			No electrical test required.				
E. Furnace Shell	3.3.1.4.1	3086-200-60A 3086-401-30		1. Heat sink operates without electrical malfunction.	1a. Trace circuit No. DA-3B to identify and locate electrical components.	LOG PAGE 141	[signature]	R.F. Pandlk 7/11/71
					1b. Observe, detect and record heak sink electrical malfunctions.		[signature]	
F. Vacuum System		3086-401-30		1. 480V, 3 phase service is available.	1. Measure and record 3 phase voltage service to motor control center, No. 30-1 with voltmeter.		[signature]	[signature] 7-1-71
		3086-100-44 3086-401-30 3086-402-00A 3086-600-20C		2. Motors on mechanical pumps, Nos. 20-1 and "Roots" type blower, No. 44-1, operate without electrical malfunction.	2a. Trace circuit Nos. 1A, 1B, 1C, 1D, and 1E on Ref. 401-30 and 402-00A to identify and locate electrical components	LOG PAGE 118	[signature]	[signature] 7-2-71
					2b. Observe, detect, and record electrical malfunctions.	LOG PAGE 118	[signature]	[signature] 7-14-71

ACCEPTANCE TEST PLAN
SECTION II. ELECTRICAL OPERATION

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
All Components	4.4.1(b)			1. The following criteria applies to all component tests: No electrical malfunctions, including short circuits, fuse burn-out, breaker disconnect, or other electrical failure.	1. All electrical components shall be demonstrated to perform properly.	–	[illegible]	R P [illegible] 7/23/71
A. Work Load Support				No electrical test required.				
B. Susceptor				1. See Section IV.	1. See Section IV.			
C. Induction Heating Coil	3.3.1.6.3	3086-490-10G		1. The coil is electrically insulated. No arcing permitted.	1. High voltage test per Inductotherm Test Procedure No. 10G-A-3948. 1a. Connect induction coil to 5000 VDC voltage supply. Verify connection.	LOG PAGES 126, 97	[illegible]	[illegible] 7-5-71
					1b. Probe entire coil surface with ground wire.		[illegible]	
					1c. Detect by sight and sound arcing through electrical insulation on coil.		[illegible]	
					1d. Record location of arc and immediately notify ANSC and Cragmet Project Managers.		[illegible]	
D. Thermal Insulation	3.2.2.1(d)			No electrical test required.				
E. Furnace Shell	3.3.1.4.1	3086-200-00A 3086-401-30		1. Heat sink operates without electrical malfunction.	1a. Trace circuit No. DA-3B to identify and locate electrical components.	LOG PAGE 141	[illegible]	[illegible] 7/11/71
					1b. Observe, detect and record heak sink electrical malfunctions.		[illegible]	
F. Vacuum System		3086-401-30		1. 480V, 3 phase service is available.	1. Measure and record 3 phase voltage service to motor control center, No. 30-1 with voltmeter.		[illegible]	[illegible] 7-8-71
		3086-100-44 3086-401-30 3086-402-00A 3086-600-20C		2. Motors on mechanical pumps, Nos. 20-1 and "Roots" type blower, No. 44-1, operate without electrical malfunction.	2a. Trace circuit Nos. 1A, 1B, 1C, 1D, and 1E on Ref. 401-30 and 402-00A to identify and locate electrical components	LOG PAGE 118	[illegible]	[illegible] 7-2-71
					2b. Observe, detect, and record electrical malfunctions.	LOG PAGE 118	[illegible]	[illegible] 7-15-71

ACCEPTANCE TEST PLAN - SECTION II - ELECTRICAL OPERATION

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
G. Inert Gas Flow Control System				No electrical test required.				
H. Power Supply		3086-490-20		1. 480V, 3 Phase, 60 H_2 service to power supply tripler transformers. is available.	1. Measure and record 3 phase voltage to tripler transformers No. 20-9 with voltmeter.		[signature]	[signature]
				2. Power supply output.	2. Power supply load test.		[signature]	
		3086-401-20A 3086-410-10A		2a. Power supply output threshold is 20 KW, maximum.	2a. Secure vacuum system for startup.		[signature]	
	3.3.1.10.1			2b. Power supply capacity is 1500 Kw min.	2b. Set selector mode switch No. 20-5 on "manual".	ACTUAL OF 20KW	[signature]	[signature] 7/1/7
				2c. Power supply operates without electrical malfunction.	2c. Turn on main line contactor No. 10-8.		[signature]	
				2d. Silicon rectifier output is variable between 0 and 100 vdc and has a maximum output of 100 amperes.	2d. Record kilowatts, volts, and amperes shown on meters Nos. 10-6, 10-3 and 10-2, respectively.	DATA SHEETS	[signature]	[signature]
					2e. Increase power with rheostat No. 10-10 in 150 Kw increments every 5 minutes. Remove capacitance from circuit, switch No. 10-12 when rheostat reaches maximum adjustment. Return rheostat to minimum position and continue to increase power.		[signature]	
					2f. Repeat as required to attain 1500 Kw, minimum.		[signature]	
					2g. Record as per 2d above every 5 minutes and before each capacitance change.		[signature]	
					2h. Measure and record voltage and ampere output of SCR No. 20-15 output as 2g. above.		[signature]	
		3086-490-40		3. No voltage or heating detected on exposed electrically conductive surfaces near the coil power ports. Surfaces TBD during testing.	3a. Measure and record voltage to ground on metal surface near the coil power ports Nos. 40-1.		[signature]	[signature] 8/16/71
					3b. Measure and record temperature of metallic surfaces near the coil power ports.		[signature]	

ACCEPTANCE TEST PLAN - SECTION II - ELECTRICAL OPERATION

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA		OPERATION		OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
I. Cooling Water		3086-401-30 3086-490-30		1.	480v, 3 Phase 1, 60 Hz service to Baltimore Air Coil water cooling tower.	1.	Measure and record 3 phase voltage service to B.A.C. No. 490-30 with a voltmeter.		[illegible]	[illegible]
				2.	BAC operates without electrical malfunction.	2a.	Trace circuit 401-30 to identify and locate electrical components.	LOG PAGE 94	[illegible]	[illegible] 6-13-71
						2b.	Observe, detect, and record B.A.C. and malfunctions.		[illegible]	
		3086-401-30 3086-402-00A 3086-600-30B		3.	Normal and emergency water pump operates without electrical malfunction.	3a.	Trace circuits 2A and 3C on Dwg 401-30 and 402-00A to identify and locate electrical components.	LOG PAGES 119,122,123	[illegible]	[illegible] 7-6-71
						3b.	Observe, detect, and record normal and emergency and normal pump motors, Nos. 30-3, malfunction on circuits Nos. 2A and 3C.	SAME AS ABOVE	[illegible]	
		3086-600-30B NPE 30-5-70A NPE 30-10-70		4.	Emergency Water Pump System	4.	Emergency Water Pump Test	LOG PAGE 119	[illegible]	
				4a.	Emergency water pump is automatically powered by emergency propane generator during a simulated power outage.	4a.	Turn on normal water pump No. 30-3.	LOG PAGE 122	[illegible]	[illegible] 7-7-
				4b.	Level indicator switch operates without electrical malfunction.	4b.	Open valves No. 70A-V-1 and 70A-V-2 and 70A-V-6.	LOG PAGE 122	[illegible]	[illegible] 7/7/71
						4c.	Shut off normal pump power and auxiliary breaker No. 10-70 to simulate power outage.		[illegible]	
						4d.	Hear propane generator (ANSC supplied) starts up when main power shutoff.	LOG PAGE 122	[illegible]	
						4e.	Hear the emergency water pump start up when the water level in the hot well reaches the upper limit of the level indicator switch No. 30-23.	LOG PAGE 122	[illegible]	
. Instrumentation Controls, and Control Cubicle	3.3.1.2.1(J)	3086-401-30A 3086-410-10A		1.	Control panel is automatically powered by emergency propane generator during a simulated power outage.	1.	Observe control panel No. 410-10 lights are lit during I.4e above.	LOG PAGES 122,141	[illegible]	[illegible] 7/1/71
				2.	Control panel lights are lit when light test switch is turned on.	2a.	Turn on test switch No. PB169 (Dwg. 410-10).	SAME AS ABOVE	[illegible]	
						2b.	Observe that all lights on control panel No. 410-10 are lit.	SAME AS ABOVE	[illegible]	

COMPONENT	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY AN
		3086-410-10		3. Two pressure recorders Nos. 10-37 and 10-37, a pressure gauge No. 10-1, are calibrated to within 1% of full scale deflection.	3a. Secure vacuum system according to procedure in Operating Manual, Paragraph TBD.		Gratcoff	[illegible] 7-
					3b. Reduce chamber pressure to 50 microns Hg.		Gratcoff	
					3c. Turn on pressure recorders Nos. 10-37 and 10-38, and adjust readings to pressure measured by vacuum gauge No. 10-2.		Gratcoff	
					3d. Adjust pressure gauge No. 10-1 as above.		Gratcoff	
					3e. Read 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 microns Hg, and readjust as necessary so that maximum error is within 1% of full scale deflection.		Gratcoff	
	3.3.1.12.3	3086-401-20 3086-410-10		4. Two temperature recorders, No. 20-4 are accurate to ± 1 Mv.	4a. Turn on two strip chart temperature recorders No. 20-4.	LOG PAGES 188, 218	Gratcoff	G.W. Haug[illegible]
					4b. Set mode switch 20-5 on "manual".		Gratcoff	
					4c. Input a standard 50 mv signal to each recorder using a calibrated potentiometer.		Gratcoff	
					4d. Record full scale deflection.		Gratcoff	
					4e. If required, adjust recorders to read full scale deflection.		Gratcoff	
					4f. Repeat 4c above for 40, 30, 20, and 10 mv.		Gratcoff	
					4g. Record indicator deflection for each step in 4f.		Gratcoff	
					4h. If required, readjust recorder for proportional scale reading required in 4g.		Gratcoff	
		3086-410-10		5. Two duplex cam time plotters, Nos. 10-23, are accurate to ± TBD mv.	5. Repeat Paragraph 4 above, for TBD mv full scale deflection and TBD mv increments.	LOG PAGE 239	Gratcoff	G.W. Haug[illegible]

ACCEPTANCE TEST PLAN
SECTION III. SAFETY INTERLOCKS

SYSTEM	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
All Systems	3.1.2.5.2.1			1. The following criteria apply to all tests.	1. Perform a test to determine whether an unsafe condition exists and record results.		[illegible]	[illegible]
				1a. In all instances where known hazards exist and cannot be eliminated, appropriate protective systems shall be employed consistent with established safety codes or standards and/or accepted industrial practices.				
				1b. Where it is not possible to preclude the existence or occurrence of a known hazard, reliable devices shall be employed for timely detection of the condition and the generation of an adequate warning signal. Warning signals shall be standardized within like types of systems to minimize the probability of improper personnel reaction to the signal(s).				
	3.1.2.5.2.2			1c. Noise levels shall not exceed limits for eight hour exposure to personnel, as defined in the Walsh-Healy Act 41CFR 50-204. Note: No excessive noise level is anticipated.				
				1d. Investigate any condition discovered during				
		3086-410-10A		2. All control panel lights are lit when tested.	2a. Push light test button No. 10-PB 169.	LOG PAGE 146	[illegible]	G.W. Haughton 7-12-71
					2b. Observe and record any lights not lit and on control panel No. 410-10, Compartment "A".		[illegible]	
					2c. Push light test buttons on the control panel, Compartment "B".		[illegible]	
					2d. Observe and record any lights not lit on Section 7.		[illegible]	
A. Cooling Water		3086-600-30		1. Water trouble light turns on and horn sounds during simulated cooling water pressure loss.	1a. Turn on normal water pump No. 30-3.	LOG PAGE 91	[illegible]	G.W. Haughton 6-21-71
					1b. Open valves Nos. 30-9.		[illegible]	
					1c. Push reset button PB-167.		[illegible]	
					1d. Throttle valves No. 30-9 at 2nd level to induce water pressure loss.		[illegible]	
					1e. Observe all pressure gauges No. 30-12 at the 2nd level module and record pressures when alarm is sounded.		[illegible]	
					1f. Observe that light Nos. 150, 151, 152, 160, 161, 164, and 165 turn [illegible]		[illegible]	

SYSTEM	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
					1g. Repeat 1b through 1f at 3rd level module valve and gauges.		J. Metcalf	
		3086-600-30 3086-410-10A		2. Water trouble lights turn on and horn sounds during simulated water flow failure.	2a. Turn on normal pump No. 30-3.	206 Page 9.1	J. Metcalf	[illegible] 6-21-71
					2b. Open valves No. 30-9.		J. Metcalf	
					2c. Push reset button PB-167.		J. Metcalf	
					2d. Close valves Nos. 30-9 to simulate water failure.		J. Metcalf	
					2e. Observe that light Nos. 150, 151, 152, 160, 161, 164 and 165 turn on and horn sounds.		J. Metcalf	
					2f. Push button PB-168 to silence alarm.		J. Metcalf	
		3086-600-30		3. Horn sounds during simulated cooling water overtemperature for each temperature switch.	3a. Adjust all temperature limit switches No. 30-17, one at a time, to a setting at which the alarm will sound.		J. Metcalf	R.P. Bartik 7/1/71
					3b. Observe that each switch when adjusted will sound the horn.		J. Metcalf	
				4. The heat sink is automatically closed during a simulated overtemperature of the bottom shell jacket water temperature switch.	4a. Open the heat sink.		J. Metcalf	
					4b. Adjust temperature limit switch NO. TBD to a setting at which the heat sink is observed to close.		J. Metcalf	R.P. Bartik 7/1/71
		3086-410-10A		5. Water trouble lights turn on and horn sounds during simulated water leak inside shell and heat exchanger.	5a. "Jumper" water leak switches Nos. TBD in shell and heat exchanger.		J. Metcalf	R.P. Bartik 7/1/71
					5b. Observe that lights 154 and 156 turn on, and listen for the trouble horn.		J. Metcalf	
		3086-600-30		6. Emergency Pump light turns on and horn sounds when emergency pump operates.	6a. Turn on emergency water pump No. 30-3.		J. Metcalf	
					6b. Observe trouble light No. 157 turns on and horn sounds.		J. Metcalf	R.P. Bartik 7/1/71

ACCEPTANCE TEST PLAN - SECTION III - SAFETY INTERLOCKS

SYSTEM	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSO
B. Vacuum System		3086-600-20 3086-410-10A		1. During vacuum operation, main vacuum valve closes automatically, trouble light turns on and horn sounds when chamber pressure rises above 20 ± 2 mm Hg vacuum.	1a. Open main vacuum valve No. 20-4, with chamber pressure at less than 20 mm Hg pressure. Measure pressure with gauge No. 10-2.		[illegible]	
					1b. Set switch No. 10-PB158 on automatic.	Reset at 35 mm Hg	[illegible]	R.P.Pack[illegible] 7/11/7[illegible]
					1c. Increase chamber pressure by introducing inert gas at 1 SCFM.		[illegible]	
					1d. Record pressure at which valve is heard to "slam" shut.	LOG PAGE 139	[illegible]	[illegible] 7-10-7[illegible]
					1e. Observe that light No. 166 turns on and horn sounds.		[illegible]	
		3086-410-10		2. During positive pressure operation, tank overpressure trouble light turns on and horn sounds when the chamber pressure exceeds 3 psig.	2a. Secure furnace lid for greater than 3 psig release pressure.		[illegible]	G.W. Haug[illegible] 7-[illegible]
					2b. Increase chamber pressure to 3-4 psig by introducing inert gas at 1 SCFM.		[illegible]	
					2c. Observe that fault light No. 163 turns on and horn sounds.		[illegible]	
				3. Gas cooling fan shuts off automatically, trouble light turns on, and horn sounds during simulated gas overtemperature.	3a. Turn on gas cooling fan.		[illegible]	
					3b. Adjust temperature limit switch No. TBD to a setting at which the fan is heard to shut off.		[illegible]	G.W. Haug[illegible] 7-11-[illegible]
					3c. Observe that light No. 162 turns on, and horn is heard.		[illegible]	
[illegible]. Power Supply		3086-410-10		1. Power supply trouble lights turn on when tested.	1a. Push the test button below each trouble light on control panel 410-10, Compartment B.	LOG OF EACH TEST	[illegible]	G.W. Haug[illegible]
					1b. Observe that all lights operate.		[illegible]	
		3086-410-10		2. "Door Interlock" and "induction off" trouble lights turn on, and horn sounds when cabinet doors are opened.	2a. Open and close each door on power supply cabinets located on 2nd and 3rd level.		[illegible]	R.P.Pack[illegible] 8/1[illegible]
					2b. Observe that the door interlock light No. 10-7 and light 10-15 are lit, and horn sounds when each door is opened.		[illegible]	

SYSTEM	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
		3086-600-30 3086-410-10		3. "Cabinet water pressure" and "induction off" trouble lights turn on, and horn sounds when water is shut off.	3a. Shut off and turn on valves 30-14 on the 2nd and 3rd level.	Loc PAGE 112	[illegible]	[illegible] 7-1-71
					3b. Observe that water pressure light 10-7 and light 10-155 are lit, and horn sounds when each valve is turned on.		[illegible]	
				4. "Tripler overtemperature" and "induction off" trouble lights turn on, and horn sounds when water is over <u>TBD</u> °C.	4. Test TBD.		[illegible]	[illegible] 7/1/71
				5. "Line overload" and "induction off" lights turn on and horn sounds when line is overloaded.	5. Test TBD.		[illegible]	[illegible] 7/1/71
				6. "Overpower" and "induction off" lights turn on, and horn sounds when output is more than 1750 Kw.	6. Test TBD.	Adjusted to 1875 KW	[illegible]	[illegible] 7/1/71
				7. "Overvoltage" and "induction off" lights turn on, and horn sounds when voltage is over 600V.	7. Test TBD.		[illegible]	[illegible] 7/1/71
				8. "Ground leak" and "induction off" lights turn on and horn sounds when a coil to ground short is simulated.	8. Test TBD.		[illegible]	[illegible] 7/1/71
Temperature Controller		3086-300-20 3086-410-10		1. "Loss of continuity" and "induction off" lights turn on, and horn sounds during a simulated thermocouple failure.	1. Unplug a lead wire to thermocouple No. 20-12 to simulate thermocouple failure.		[illegible]	[illegible] 7/1/71
					2. Observe that lights 10-153 and 10-155 are turned on and horn sounds.		[illegible]	

ACCEPTANCE TEST PLAN
SECTION IV. PERFORMANCE

FUNCTIONAL CHARACTERISTIC	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
l Tests				1. The following criteria applies to all tests:	1. The furnace operating procedures in the Operating Manual will be followed for all operations performed.	LOG BOOK	J. Metcalf	—
	4.4.1(d)			1a. Performance is to be met within the normal design ratings of all equipment.				
	3.1.1			1b. The furnace heats the graphite work load to the maximum operations temperature (2750°C) with the performance requirements described below. (Note: Do not exceed 2750°C at any time.)	2. Designated furnace parameters will be recorded every 15 minutes, unless otherwise noted.	DATA SHEETS	J. Metcalf	G.W. Haughton
					3. Two manual optical pyrometers, Cragmet and ANSC Equipment, will be used to calibrate the automatic temperature sensors every hour on the hour, unless otherwise noted.	Spot Calibration WAIVED BY L.A. SHURLEY 8/7/71	J. Metcalf	G.W. Haughton
Temperature Capability	3.1.1.1 3.1.1.1.4	3086-401-20A 3086-410-10A		1. High Temperature Mode	1. High Temperature Test			
				1a. The rate of temperature increase is controllable at 15 to 60°C per hour between 120°C and 2600°C. For this test, the rate is 15° ± 2°C per hour between 120°C to 240°C, and during capacitance switching operations.	1a1. Position the graphite simulated work load in the furnace according to Drawing No. T-1050171.	LOG PAGE 182	J. Metcalf	[illegible] 7-21-71
					1a2. Prepare furnace for temperature cycling in an argon atmosphere, 3 psig and 3 SCFM.		J. Metcalf	G.W. Haughton 8-3-71
					1a3. Manually control temperature from room temperature to 120°C at TBD °C per hour.	200°/hr	J. Metcalf	
					1a4. Automatically control heating rate of 15°C per hour from 120°C to 240°C.	LOG PAGE 230	J. Metcalf	G.W. Haughton 8-3-71
					1a5. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-3.		J. Metcalf	
					1a6. Manually control heating rate at 200°C per hour, maximum, from 240°C to within approximately 20°C of the temperature where capacitance switching was required during Electrical Operations, Paragraph II.H.2 above.	LOG PAGE 195	J. Metcalf	G.W. Haughton 7-24-71
					1a7. Then control the rate of temperature rise at 15°C per hour until the capacitance switch is completed, and one hour thereafter. Note: Should the temperature reach 850°C, proceed to Operation 1b1., and then complete 1a7.	LOG PAGE 195	J. Metcalf	
					1a8. Then, calculate and record actual rates of temperature change at 15 minute		J. Metcalf	

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FUNCTIONAL CHARACTERISTIC	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
	3.1.1.1.2	3086-401-20A		1b. The furnace temperature shall be controllable within ± 2% of any set point, set between 850°C and 2750°C. For this test, the controllability is determined at 850°C ± 5°C, set point temperature.	1b1. Manually change temperature to 850°C ± 5°C, as required, and automatically maintain this set point temperature for 30 minutes.	700°C in lieu of 850°C per RP [illegible]	JMetcalf	G.W. Haughton 7-24-71
					1b2. Calculate and record the temperature controllability and report in percent of set point. Required information is on recorder 20-3.		JMetcalf	[illegible] 7-24-71
	3.1.1.1.4	3086-401-20A 3086-410-10A		1c. The rate of temperature increase shall be controllable at 15 to 60°C per hour between 120°C and 2600°C. For this test, the rate is 60°C per hour between 2180 and 2600°C.	1c1. Manually control temperature at approximately 200°C per hour between the current temperature and 2180 ± 20°C.	Changed to hold 1800°C then proceed to test 1g5 RP [illegible]	JMetcalf	R.R. [illegible] 8/7/71
					1c2. Automatically control the rate of temperature rise at 60°C per hour to 2600°C.		JMetcalf	
					1c3. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-3.	LOG PAGE 195	JMetcalf	G.W. Haughton 7-24-71
				1d. For information only, determine rate of temperature increase above 2600°C.	1d1. Automatically control temperature from 2600 to 2750°C at 60°C per hour.	Rate of [illegible] [illegible]	JMetcalf	
					1d2. Measure with manual optical pyrometer and record temperatures at all viewports every 15 minutes.	MAXIMUM TEMP 2555°C UNCORRECTED	JMetcalf	
					1d3. Calculate and record the rate of temperature rise.		JMetcalf	
	3.1.1.1.2	3086-401-20A		1e. The furnace temperature shall be controllable within ± 2% of any set point, set between 850°C and 2750°C. For this test, the controllability is determined at 2750°C, set point temperature.	1e1. Manually adjust the temperature to 2750°C, maximum, and automatically maintain this set point temperature for 5 hours.	2550 [illegible] +50° [illegible] +100 [illegible] smoke	JMetcalf	
					1e2. Measure and record the top, middle and bottom viewport temperature every 15 minutes with manual optical pyrometers.		JMetcalf	
					1e3. Calculate and record the temperature controllability during 1e2. and report as ± % of set point temperature.		JMetcalf	
	3.1.1.1.3			1f. The axial temperature gradient is within 100°C.	1f. Concurrently with operation 1e., calculate and record the top to bottom viewport temperature gradients.		JMetcalf	

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FUNCTIONAL CHARACTERISTIC	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANS
	3.1.1.4			1g. The rate of temperature decreases shall be controllable at 15 to 60 °C per hour between 2750 and 1500°C. For this test, the rate of decrease is 15° ± 2°C per hour between 2750 and 2580°C, and 60° ± 6°C per hour between 2680°C and 1800°C.	1g1. After the 5-hour hold, automatically control the cooling rate at 15°C per hour between 2750°C and 2680°C.	1in	Jmetcalf	[illegible]
					1g2. Then calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-3.		Jmetcalf	
					1g3. Automatically control the cooling rate at 60°C per hour to 1800°C.		Jmetcalf	
					1g4. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder 20-3.		Jmetcalf	
					1g5. Change the furnace atmosphere from 3 psig argon to vacuum, approximately 50μ.	20mm	Jmetcalf	
					1g6. Automatically control the cooling rate at 60°C per hour to 1500°C.		Jmetcalf	[illegible] 7-25-7[illegible]
					1g7. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder 20-3.		Jmetcalf	[illegible] 7-25-7[illegible]
	3.1.1.2.5			1h. The forced gas cooling system is sufficient to enable the furnace to cool from 2750°C to 200°C within seven days at a rate not to exceed 60°C per hour.	1h1. Automatically control the cooling rate at 60°C per hour, maximum, between 1500°C to 1000°C.		Jmetcalf	[illegible] 7-26-7[illegible]
					1h2. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-3.		Jmetcalf	
					1h3. Automatically control temperature and manually control the heat sink system, as required, to maintain a cooling rate of 60°C per hour, maximum, to 800°C.		Jmetcalf	
					1h4. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-3.		Jmetcalf	
					1h5. Manually control the heat sink and thermally regenerative atmosphere gas cooling systems to maintain a cooling rate of 60°C per hour, max., to 200°C.		Jmetcalf	
					1h6. Then calculate and record actual rates of temperature change at 15 minute		Jmetcalf	

FUNCTIONAL CHARACTERISTIC	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
					1h7. Calculate and record the time required to cool the furnace from 2750°C to 200°C.		[illegible]	
	3.1.1.1.2			2. Low Temperature Mode	2. Low Temperature Test			
				2a. The furnace temperature is controllable within ± 5°C of any set point, set between 120°C and 850°C. For this test, the temperature is controllable at ± 5°C of 120°C ± 5°C, set point.	2a1. Place simulated work load Dwg. No. T-1050171 in retort, connect retort control system, and position retort in furnace.		[illegible]	[illegible] 1-2[illegible]
					2a2. Maintain nitrogen furnace atmosphere at 3 psig and 3 SCFM.		[illegible]	
					2a3. Adjust retort pressure differential switch No. TBD at 0.2 lbs above the operating pressure differential. Set retort alarm switch No. TBD on automatic.		[illegible]	
					2a4. Manually control retort temperature from room temperature to 120°C ± 5°C at TBD °C per hour.		[illegible]	[illegible] 1-3[illegible]
					2a5. Automatically control the retort set point temperature at 120°C for 30 minutes. Record the temperature on recorder 20-3 every 5 minutes.		[illegible]	
					2a6. Calculate and record the temperature deviation. Report as ± °C temperature range about the set point.		[illegible]	[illegible] 1-30-[illegible]
	3.1.1.1.4(b)			2b. The rate of temperature increase is controllable at 5 to 15°C per hour between 120 and 850°C. For this test, the rate is controllable at 5° ± 2°C per hour between 120 and 160°C, and 15°C ± 2°C between 600 and 850°C.	2b1. Automatically control the rate of retort temperature rise at 5°C per hour between 120°C and 160°C.	CAMS NOT ACCURATELY PREPARED	[illegible]	[illegible] 8/11/71
					2b2. Then, calculate and record actual rates of temperature at 15 minute intervals. Required information is on recorder No. 20-3		[illegible]	
					2b3. Manually control the rate of temperature rise between 160 and 600°C at 200°C per hour, maximum (Inf. only).		[illegible]	

FUNCTIONAL CHARACTERISTIC	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
					2b4. Automatically control the rate of retort temperature rise at 15°C per hour between 600 and 850°C. Monitor the susceptor temperature and do not allow the susceptor temperature to exceed 950°C. (This may be in lieu of attaining an 850°C retort temperature.)	LOG PAGE 223 DATA SHEETS	Jmetcalf	
					2b5. Then, calculate and record actual rates of temperature at 15 minute intervals. Required information is on recorder No. 20-3.		Jmetcalf	
	3.1.1.1.2			2c. The furnace temperature is controllable within ± 5°C of any set point, set between 120°C and 850°C. For this test, the temperature is controllable at ± 5°C of 850° ± 5°C, set point.	2c1. Manually adjust the retort temperature at 850 ± 5°C, and automatically maintain the set point temperature for 30 minutes. Record retort temperature on recorder No. 20-3 every 5 minutes.		Jmetcalf	[illegible] 7-31-71
					2c2. Calculate and record the temperature deviation. Report as ± °C temperature range about the set point.		Jmetcalf	
				2d. Determine cooling rate for information only.	2d1. Manually control temperature, and heat sink and forced gas convective cooling systems to cool down to 200°C at 60°C per hour, maximum.		Jmetcalf	[illegible] 8-4-71
					2d2. Then, calculate and record actual rates of temperature change at 15 minute intervals. Required information is on recorder No. 20-3.		Jmetcalf	
B. Furnace Atmosphere	3.1.1.2.2	3086-410-10		1. <u>Vacuum System</u>	1. <u>Rate of Evacuation Test</u>			
	3.1.1.2.2	3086-410-10		1a. The cold furnace is evacuated of air at ambient conditions to 50 microns in 30 minutes.	1a1. Secure vacuum system and pump down chamber.		Jmetcalf	[illegible] 8-5-71
					1a2. Clock and record every 5 minutes time to reduce shell pressure to 50 microns. Measure pressure on gauge No. 10-2.		Jmetcalf	
	3.1.1.2.3	3086-410-10		2. The cold furnace is back-filled with air from 50 microns to ambient pressure in 20 minutes, maximum.	2. Rate of back-fill test.			
					2a1. After above, open furnace air release valve No. <u>TBD</u>.		Jmetcalf	
					2a2. Clock and record every 5 minutes time to increase shell pressure to ambient conditions. Measure pressure on gauge No. 10-2.		Jmetcalf	

FUNCTIONAL CHARACTERISTICS	SPECIFICATION PARAGRAPH	DRAWING REFERENCE	TEST SEQUENCE	CRITERIA	OPERATION	OBSERVATIONS	CERTIFICATION BY CRAGMET	VERIFICATION BY ANSC
. Leak Rates	3.1.1.3 3.1.1.3.1			1. The shell helium gas leak rate is 1×10^{-4} mm Hg per minute pressure rise at 75 microns.	1. Complete shell leak rate test as per specification, paragraph 4.2.1 (a,b,c).	LOG PAGE 144	Jmetcalf	RP Pratt 7/14/71
				2. The shell helium gas leak rate is 1×10^{-4} mm Hg per minute pressure decay at 3 psig.	2. Complete shell leak rate test as per specification, paragraph 4.2.1 (d,e).		Jmetcalf	
				3. The induction coil helium gas leak rate is 1×10^{-6} std cc per second, maximum, at 1 micron Hg coil pressure, or less.	3. Complete induction coil leak test as per specification, paragraph 4.2.2. The furnace shell or coil may be filled with helium in lieu of use of a plastic shroud.	LOG PAGE 149	Jmetcalf	RP Pratt 7/14/71
				4. No leaks in water system visually detected when in operation.	4. Visually observe water leaks during Mechanical Operations Test No. I.I.2.	LOG PAGES 158, 160, 184, 185	Jmetcalf	B.W. Haughton 7-17-71
. Furnace Cooling	3.1.1.4	3086-600-30		1. The furnace cooling water temperature is not greater than 70°C at the induction coil and furnace shell outlet.	1. Cooling water temperature test.		Jmetcalf	
					1a. Set the induction coil and shell outlet temperature limit switches, Nos. 30-17, at 70°C and record time and location when overtemperature alarm No. TBD is activated.	DATA SHEETS	Jmetcalf	
					1b. Read and record the outlet water temperatures of all gauges Nos. 30-21.		Jmetcalf	
	3.1.1.4.5			2. The outside temperature of the furnace shell including all attached fittings, did not exceed 50°C.	2. Chamber Temperature Test		Jmetcalf	
					2a. Continuously measure outside chamber temperature at random locations with a contact pyrometer during performance testing.		Jmetcalf	
					2b. Record temperature and location of temperatures detected in excess of 50°C.	Flange 136-145 170°F	Jmetcalf	
. Operability	3.1.2 3.1.2.1			1. Maintenance Requirement	1. Observe and record maintenance required during all acceptance testing.		Jmetcalf	RP Ram 8/11/71
				1a. No periodic maintenance is required during any 14 day operating cycle.				
	3.1.2.1			1b. No periodic maintenance is required on the induction coil or furnace shell.				
	3.1.2.2			2. Useful Life Requirement - The furnace components operate without visually detectable deterioration.	2. Visually inspect and record condition of furnace components, Specification Paragraph 3.2.2.1, before and after each furnace operation.		Jmetcalf	

APPENDIX B

ANSC SPECIFICATION NO. AGC 90278B,

FURNACE, VERTICAL, VACUUM-INERT, INDUCTION,

dated 22 May 1970

AEROJET NUCLEAR SYSTEMS COMPANY

A DIVISION OF AEROJET-GENERAL CORPORATION

CODE IDENT. NO. 05824

SPECIFICATION AGC-90278B

FURNACE, VERTICAL, VACUUM - INERT, INDUCTION

SUPERSEDING:		
AGC- DATE	AGC- DATE	AGC- DATE

RELEASES (REPLACE PAGES IN SPECIFICATION WITH LATEST CHANGE BELOW.)

REV LTR	RELEASE DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	27
	17 Apr 70																									
A	22 May 70	A				A	A	A	A	A			A	A	A	A	A	A	A	A	B	A	B	A B	B	
B	15 Mar 72			B			B	B							B		B	B	B	B						

Authorized for Release:

J. H. Yetto, Supervisor
ANSC Specifications & Standards

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Section 1. SCOPE

1.1 Scope.- This specification establishes the performance and qualification requirements for equipment identified as a vertical vacuum inert atmosphere induction furnace system.

1.2 Options.- Optional designs covered under this specification include the following:

(a) Option 1 - High Temperature Capability System
(b) Option 2 - Low Temperature Control Capability System
(c) Option 3 - Inert Gas Pressure Control System
(d) Option 4 - Forced Gas Convective Cooling System

Stipulation of a specific option includes all requirements listed in the specification under that option designation.

Section 2. APPLICABLE DOCUMENTS

2.1 Government Documents.- The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled documents list. When the requirements of this specification and subsidiary documents are in conflict the following precedence shall apply:

(a) This Specification.
(b) Document referenced herein.
(c) Documents subsidiary to those referenced herein.

SPECIFICATIONS

Federal

QQ-A-200	Aluminum Alloy Extruded Bar, Rod, and Shapes
QQ-A-225	Aluminum Alloy Rolled Bar, Rod, and Shapes
QQ-S-766	Stainless Steel Plate and Sheet

Military

MIL-P-27401	Nitrogen
MIL-A-18455	Argon

(B)

STANDARDS

Military

MIL-STD-1472	Human Engineering Design Criteria for Military Systems Equipment and Facilities

PUBLICATIONS

NASA

NHB 1700.1	NASA Safety Manual

2.2 Technical Society Documents.- The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled document list. When the requirements of this specification and subsidiary documents are in conflict, the following precedence shall apply:

(a) This Specification.
(b) Document referenced herein.
(c) Documents subsidiary to those referenced herein.

American Society of Mechanical Engineers

ASME Boiler and Pressure Vessel Code

American Society for Testing and Materials Standards

A193-68	Alloy-Steel Bolting Materials for High Temperature Service
A194-68	Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service
A240-67	Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Fusion-Welding Unfired Pressure Vessels
A276-67	Hot Rolled and Cold Finished Stainless and Heat Resistant Steel Bars
A312-64	Seamless and Welded Austenitic Stainless Steel Pipe

American Society of Heating and Ventilating Engineers

ASHVE Manual

American National Standards (ANSI)

B2.1-1960	Pipe Threads
B16.5-1961	Steel Pipe Flanges and Flanged Fittings
B31.1-1955 and Addenda	Code for Pressure Piping

Other Publications

41CFR 50-204	Walsh-Healy Act
NFPA	National Fire Code
NEC	National Electrical Code

2.3 Aerojet Nuclear Systems Company Documents.- The following documents form a part of this specification to the extent specified herein. The issue used shall be that controlled by the latest approved contractor's controlled documents list. When the requirements of this specification and subsidiary documents are in conflict, the following precedence shall apply:

(a) This Specification.
(b) Document referenced herein.
(c) Documents subsidiary to those referenced herein.

DRAWINGS

SPE 14-1-70 Building 20005 Heat Treat Facility Description

Section 3. REQUIREMENTS

3.1 Performance.-

3.1.1 Functional Characteristics.- The furnace shall be capable of heating the graphite work load to the maximum operating temperature with the performance requirements described below. The work load shall be as defined in Table I and Figures 1 and 2. The furnace shall be capable of achieving the following performance.

3.1.1.1 Temperature Capability.-

3.1.1.1.1 Maximum Temperature.-

(A) (a) The furnace shall be capable of operating at a maximum continuous operating temperature of 2200°C, within the useful life requirements of 3.1.2.2.

(b) Option 1 - High Temperature Capability - The furnace shall be capable of operating at a maximum continuous operating temperature of 2750°C, within the useful life requirements of 3.1.2.2.

3.1.1.1.2 Temperature Controllability.-

(a) The furnace temperature shall be controllable within ± 2% of any set point, set between 850°C and the maximum operating temperature.

(A) (b) Option 2 - Low Temperature Control Capability - The furnace temperature shall be controllable within + 5°C of any set point, set between 120°C and 850°C. The temperature will be measured on the work load when enclosed within a retort, to be supplied by ANSC.

(A) 3.1.1.1.3 Temperature Gradient.- The axial temperature gradient shall be within 100°C over the length of the susceptor corresponding to position of the work load when the furnace is operating at the maximum temperature capability.

3.1.1.1.4 Temperature Rate Controllability.-

(B) (a) The rate of temperature increase shall be controlled at 15 to 60°C per hour between 120°C and 2600°C. The rate of temperature increase shall be no less than 60°C per hour between 2540°C and 2600°C. The rate of temperature decrease shall be controllable at 15 to 60°C per hour between the maximum operating temperature and 1500°C.

(b) Option 2 - Low Temperature Control Capability.- The rate of temperature increase shall be controllable at 5 to 15°C per hour between 120°C and 850°C.

3.1.1.2 Furnace Atmosphere.-

(A) 3.1.1.2.1 Atmospheric Conditions.- The temperature controllability and profile, shall be maintainable with each of the following furnace atmospheres:

(a) Vacuum	50 microns, maximum
(b) Argon or nitrogen	
(1) Flow Rate	0.1 - 3.0 SCFM
(2) Pressure	50 microns - 3 psig

(A) Vacuum will not be required at temperatures which cause sublimation of carbon.

3.1.1.2.2 Rate of Evacuation.- The cold furnace shall be capable of being evacuated of air at ambient conditions to 50 microns in 30 minutes, and being held continuously for a minimum period of fourteen days.

3.1.1.2.3 Rate of Back-Fill.- The cold furnace shall be capable of being back-filled with air, nitrogen, or argon from fifty microns to ambient pressure in a maximum of twenty minutes.

(A) 3.1.1.2.4 Option No. 3, Inert Gas Pressure Control.- The shell pressure shall be controllable at 5 to 30 inches of Hg with argon or nitrogen flowing at two SCFM.

(B) 3.1.1.2.5 Option No. 4, Forced Gas Convective Cooling.-

(a) The inert gas system shall provide convective cooling sufficient to cool the furnace from 2750°C to 200°C in seven (7) days at a rate not to exceed 60°C in one (1) hour.

(b) Inert gas shall be circulated through the furnace hot zone to provide convective cooling at temperatures between 880°C and 120°C.

3.1.1.3 Leak Rates.-

3.1.1.3.1 Furnace Shell.- The maximum allowable gas leak rate of the furnace shell shall be 1 x 10^{-4} mm Hg per minute pressure rise when the vacuum system is isolated from the shell, and the pressure within the shell is 75 microns.

(A) 3.1.1.3.2 Cooling Water Channels.- All cooling water channels, including those for the furnace shell, if the ASME Boiler and Pressure Vessel Code is applicable, induction coil, vacuum system, and supply and outlet lines, shall not leak any water when tested at 100 psig.

3.1.1.4 Furnace Water Cooling.-

3.1.1.4.1 Capacity.- The cooling water system shall be supplied by the contractor and shall have a capacity sufficient to provide coolant for the induction coil, furnace shell, and vacuum pump as required to meet the requirements of this specification.

3.1.1.4.2 Backup System.- The cooling system shall be capable of providing for an automatic alternate coolant supply in the event of major component or electrical power failure.

3.1.1.4.3 Water Temperature.- The cooling water shall not exceed 70°C at the induction coil and furnace shell outlets when the heating zone is operated continuously at the maximum operating temperature.

(A) 3.1.1.4.4 Water Flow.- All coolant channels shall be protected from blockage by particulate matter (greater than 0.05 inch diameter).

3.1.1.4.5 Furnace Shell Cooling.- The outside wall temperature of the furnace shell, including all attached fittings, shall not exceed 50°C when operating continuously at the maximum operating temperature.

3.1.2 Operability.- The furnace system shall be capable of being operated within the following requirements.

(A) 3.1.2.1 Maintainability.- No periodic maintenance shall be required within a time period of fourteen days while the furnace is being operated according to the performance requirements of Section 3.1.

3.1.2.1.1 Maintenance and Repair Cycles.- There shall be no periodic maintenance required on the induction coil or furnace shell.

3.1.2.1.2 Service and Accessibility.- All components of the furnace which require periodic maintenance shall be accessible for repair. Required ladders, staircases, and platforms shall be provided by the contractor.

3.1.2.2 Useful Life.- The furnace system will have a minimum useful life of eight years, allocated as follows:

Rated Operating Life

(a)	Time	5000 hours, minimum
(b)	Thermal Cycles	50, maximum

(A) A thermal cycle shall conform to the performance requirements in Section 3.1, and a maximum hold time of five hours at or below the maximum operating temperature.

3.1.2.3 Environmental.-

3.1.2.3.1 Natural.- The water available for furnace system cooling has a hardness value of 30 $\pm$ 5 ppm as calcium carbonate, $CaCO_3$.

3.1.2.3.2 Induced.- The inert gases available for the furnace system atmosphere have the following impurities.

(a) Nitrogen as specified in MIL-P-27401 (99.997% N_2)
(b) Argon as specified in MIL-A-18455B (99.998% Ar)

The furnace interior, including the shell, induction coil, and vacuum system, will be exposed to an atmosphere consisting of argon, nitrogen, hydrogen, methane, carbon dioxide, carbon monoxide, and particulate carbon. The quantity of gases to be released by the work load are given in Figure 2.

3.1.2.4 Human Performance.- The furnace system controls will provide the operator with a procedure which meets the standards as given in MIL-STD-1472.

3.1.2.4 Safety.- All components, appurtenances, support equipment, etc., shall be designed and operated so that no single failure or credible combination of errors, malfunctions or accidents can cause personnel injury, and/or serious facility damage or work load loss. This philosophy requires the use of a formal hazards analysis which results in a categorization of potential hazards and documents the analysis and proposed procedures to reduce any undue consequences to acceptable levels. The hazards analysis technique is further described in Section 3.1.2.5.2.2(a).

3.1.2.5.1 Documents.- The following documents shall be used as stated to aid in achieving safety goals.

(a) The following documents shall be complied with:

(1) Walsh-Healy Act, 41 CFR 50-204

(2) National Fire Code (NFPA)

(3) Current Threshold Limit Values, American Conference of Government Industrial Hygienist

(4) National Electric Code (NEC)

(b) The following documents may be used as a guide:

(1) American Society of Heating and Ventilating Engineers Manual

(2) NASA Safety Manual NHB-1700.1 (V 1)

3.1.2.5.2 Requirements.-

3.1.2.5.2.1 General Requirements.- The following safety requirements, listed in order of preference, shall be applied to the designs:

(a) Protective Systems - In all instances where known hazards exist and cannot be eliminated, appropriate protective systems shall be employed consistent with established safety codes or standards and/or accepted industrial practices.

(b) Warning Devices.- Where it is not possible to preclude the existence or occurrence of a known hazard, reliable devices shall be employed for timely detection of the condition and the generation of an adequate warming signal. Responses to warning signals shall be delineated in emergency plans. Warning signals shall be standardized within like types of systems to minimize the probability of improper personnel reaction to the signal(s).

(c) Special Procedures.- Where it is not possible to reduce the magnitude of existing or potential hazards through design, protective systems, or the use of warning devices, appropriate emergency procedures shall be developed.

3.1.2.5.2.2 Special Requirements.-

(a) The contractor shall prepare and submit with his proposal, a preliminary hazards analysis and the hazard analysis procedure he intends to use during the contract period. A final hazards report shall accompany the detail drawings, etc. required for ANSC Engineering Department approval by Paragraph 6.3. The following hazard category definitions will be used in the analysis.

Category I - Negligible. Condition(s) such that personnel error, environment, design characteristics, procedural deficiencies or subsystem or component malfunction will not result in damage or personnel injury.

Category II - Marginal. Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction can be counteracted or controlled without major damage or any injury to personnel.

Category III - Critical. Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will cause major equipment damage or personnel injury, or will result in a hazard requiring immediate corrective action for personnel or system survival.

Category IV - Catastrophic. Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will severely degrade system performance and cause subsequent system loss, or death or severe injuries to personnel.

(b) Category III or IV hazard conditions shall be precluded from designs to the maximum practical extent. Any design which includes a Category III or Category IV hazard condition which cannot be eliminated will require review by ANSC. The analysis of Category III or Category IV hazard conditions will be documented together with a proposed procedure for reducing the consequences of the hazard to an acceptable level.

(A) (c) The furnace design shall preclude the accumulation of a mixture of combustible gases which can lead to explosion/fire during operations. Where it is not possible to prevent the occurrence of an explosive atmosphere, ignition sources in the affected area shall be eliminated or protection against ignition otherwise provided.

(d) The furnace/facility design shall preclude the accumulation of inert/toxic gases in the operating area. Reliable devices shall be utilized for timely detection of the condition and generation of an adequate warning signal perceptible by personnel without entering the pit.

(e) The Walsh-Healy Act 41CFR 50-204 shall be followed in meeting the environmental conditions given below.

(1) Fresh air shall be supplied to the pit operating area. An oxygen concentration of 20% per volume air shall be maintained at all times.

(2) Thermal environment shall be compatible with the facility ventilation capability to provide a personnel working environment in the comfort range as defined in "Heating, Ventilating and Air Conditioning Guide (ASHVE)."

(3) Noise levels shall not exceed limits for eight-hour exposure to personnel.

(4) Illumination shall be adequate for personnel to perform their work efficiently in the operating areas.

(f) The furnace system shall be fail safe, so if there is water failure, power failure, or a vacuum failure, the system will sound an alarm and automatically shut itself down in a safe manner to protect the equipment and work load. The fail safe system shall be monitored by the operator and it shall be possible to detect any fail safe circuit malfunction.

3.2 System Definition.-

3.2.1 Interface Requirements.- The furnace system described in this specification shall be physically, mechanically, and functionally suitable for operation with the Sacramento AGC Physical Plant as described below.

3.2.1.1 Schematic Arrangement.- The physical interface relationships of the furnace system and the AGC Physical Plant shall be in accordance with the description of the AGC Building 20005, Heat Treat Facility given in drawing SPE-14-1-70.

3.2.1.2 Detailed Interface Definition.- The mechanical and functional interface relationships of the furnace system shall be in accordance with the following subparagraphs:

(A) 3.2.1.2.1 Mechanical Interfaces.-

(A) 3.2.1.2.1.1 Pit Area.- The furnace shell and vacuum system shall be installed by the contractor in the pit shown in drawing SPE-14-1-70. The existing available pit area can be enlarged to 18.5 feet square by relocation of a concrete beam. Additional space of 9 by 18.5 feet, adjacent to the pit cell, is available to the furnace Contractor.

(A) 3.2.1.2.1.2 Sump Location.- The sump located at the bottom of the pit shall remain and will not interface with the proposed furnaces.

(A) 3.2.1.2.1.3 Gas Generator.- The existing gas generators are surplus equipment and may be moved by the contractor.

3.2.1.2.2 Functional Interfaces.- The service and utilities available for use by the furnace system are as follows:

3.2.1.2.2.1 Fluid.- Water, nitrogen, and argon will be available as located in drawing SPE-14-1-70. Capacities available are as follows:

(a)	Water	500-1000 GPM at 80 psi
(b)	Steam	75-100 BHP at 90 psi (located 600 feet from site)
(c)	Nitrogen	2000 SCFH continuous 4000 SCFH for one (1) hour at 4 psi
(d)	Argon	10,000 SCFM at 50 psi
(e)	Compressed Air	200-250 CFM at 80 psi (not dry)

(B)

(A) 3.2.1.2.2.2 Electrical.-

(A) 3.2.1.2.2.2.1 Power Availability.- Power will be available as located in drawing SPE-14-1-70. Capacities available are as follows:

(a) Two (2) each - 12 KV/480V, 1000 KVA 3 Ø transformers.

(b) 12K/480V, 100 KVA, 3 Ø transformer.

(c) Two (2) each - 12 KV, 2000 KVA 3 Ø feeders.

Electrical components shall be designed to a power factor rating of 0.90 minimum. Available three phase power shall maintain a balanced load to within 15 percent.

(A) 3.2.2.2.2.2 Power Switching Panel.- The facility power switching panel is identified and shall remain in service. The contractor shall use or modify the available breakers, as required.

3.2.2 Component Identification.-

3.2.2.1 Engineering Component List.- Design of the furnace system shall include the following engineering components. Each component shall be supplied and installed by the contractor. When installed, the components shall be mutually compatible to perform as required in Section 3.1.

(a) Work Load Support
(b) Susceptor
(c) Induction Heating Coil
(d) Thermal Insulation
(e) Furnace Shell
(f) Vacuum System
(g) Inert Gas Flow Control System
(h) Power Supply and Controls
(i) Water Cooling Tower
(j) Instrumentation, Controls, and Control Cubicle

3.3 Design and Construction.- The design, construction and installation of the furnace system shall be provided by the contractor, and shall conform to the following requirements.

3.3.1 General Design Features.-

3.3.1.1 Structural Criteria.- Structural design features shall be consistent with performance requirements specified herein.

(A) 3.3.1.2 Weight.- The weights of the work load components shall be as follows:

(a)	Bulk Graphite Support	6000 lbs, maximum
(b)	Fibrous Graphite	600 lbs
(c)	Option 2, Low Temperature Control Capability	
	(1) Steel Retort	3000 lbs
	(2) Bulk Graphite or Steel Support	6000 lbs, maximum

3.3.1.3 Configuration.- The configuration of the work load is defined in Figure 1.

3.3.1.4 Work Load Support.-

(a) The work load support shall be capable of maintaining the position of the work load within ± one inch, axially and diametrically, during the thermal operating cycle.

(b) Heat Sinks.- Retractable heat sinks incorporated in the workload support shall be capable of increasing the furnace cooling rate.

3.3.1.5 Susceptor.- The susceptor shall be assembled and disassembled from the furnace shell vertically employing an overhead five-ton crane.

3.3.1.6 Induction Heating Coil.-

3.3.1.6.1 Assembly and Disassembly.- The induction coil shall be mounted vertically in the furnace shell, and shall be removed vertically employing a five-ton crane.

3.3.1.6.2 Coil Movement.- The coil shall be supported in such a manner that the coil centerline shall be held within ± one inch of the furnace shell centerline.

3.3.1.6.3 Electrical Insulation.- The coil shall be electrically insulated to prevent arcing.

3.3.1.6.4 Sight Port Pass-Throughs.- A minimum of three sight port pass-throughs shall be provided on the coil to allow optical pyrometic measurement on the susceptor.

(B) 3.3.1.6.5 <u>Coil Size</u>.- The induction heating coil shall have a copper wall thickness of 0.25 inch, minimum.

(B) 3.3.1.6.6 <u>Coil Support</u>.- The induction heating coil shall be supported on the outside circumference by vertical columns which are spaced on 23 inch maximum centers.

3.3.1.7 <u>Furnace Shell</u>.-

3.3.1.7.1 <u>Type</u>.- The furnace shell shall be a cylindrical vessel with a flanged main closure.

(B) 3.3.1.7.2 <u>Main Closure</u>.- The main closure shall be operated with a twenty-ton gantry crane, to be provided by ANSC, and secured with a quick acting spring loaded clamping device which allows gas to escape in the event of shell overpressure.

3.3.1.7.3 <u>Access Ports</u>.-

(a) Access ports shall be provided for required sight ports, inert gas and air inlet, outlet, vacuum line, thermocouple leads, pressure gauges, and power feed-throughs.

(b) <u>Option 2 - Low Temperature Control Capability</u>.- All ports specified and in addition, one inlet and one outlet port to provide two SCFM of argon, nitrogen or air flow at three psig pressure, and two thermocouple lead ports.

3.3.1.7.4 <u>Sight Ports</u>.- Sight glass viewports shall be located on the furnace shell so that optical pyrometer measurements can be made on three equally spaced locations on the susceptor corresponding to the top, center, and bottom of the work load. Additional sight ports may be provided by the contractor. The interior of the sight port glass shall be free of deposits during normal operation. The contractor shall consider employing inert gas flushing and ball valve closure.

3.3.1.7.5 Pressure Relief.- A relief valve for vacuum or pressure operation shall be provided to relieve pressure at five psig. Corrosion resistant rupture disc assemblies will be provided to relieve pressure greater than eight psig at ambient temperature. The pressure relief system shall be capable of handling the maximum gas overpressure and flow conditions, and the discharge gas shall be vented to the atmosphere in a safe manner.

(B) 3.3.1.7.6 Shell Construction.- The furnace shell shall be of double wall construction, water cooled throughout, and shall meet the performance requirements of paragraphs 3.1.1.4.

3.3.1.7.7 High Intensity Filters.- Sight glass view ports shall be equipped with removable optical filters.

3.3.1.8 Vacuum System.- The vacuum system shall be equipped with a suitable low impedence filter to protect the vacuum pumps from the furnace atmosphere, which consists, in part, of particulate graphite powder.

(B) 3.3.1.9 Inert Gas Flow System, Option No. 4, Forced Gas Convective Cooling.-

(a) Gas shall be circulated through the hot zone with a regenerative gas recirculation type system which includes a high temperature fan and water cooled heat exchanger.

(b) Inert Gas Purge.- When required in the event of an emergency, the inert gas flow system shall provide a rapid purge of the furnace.

(A) 3.3.1.10 Power Supply.- The contractor shall provide a power supply with sufficient capacity to meet the performance requirements in Section 3.1.

(A) 3.3.1.11 Water Cooling Tower.- The contractor shall provide a water cooling tower with sufficient capacity to meet the performance requirements in Section 3.1.

3.3.1.12 Instrumentation, Controls, and Control Cubicle.-

(A) 3.3.1.12.1 Control Cubicle.- One enclosed control cubicle containing all measurement, metering, recording, programming, switching, operating control equipment, and etc., shall be provided by the contractor.

3.3.1.12.2 Control Duality.- Switching shall be provided in this control cubicle to permit selective operation of this furnace and a proposed second furnace to be installed adjacent to this unit at a later date.

3.3.1.12.3 Temperature Measurement and Instrumentation.- The temperature shall be continuously and automatically controlled, programmed, and permanently recorded at any one of three locations equally spaced on the susceptor. The locations on the susceptors shall correspond to the top, center, and bottom of the axial work load when positioned within the susceptor.

(a) Controllers.-

(B)

(1) Low and middle range temperature controllers shall operate with thermocouples.

(2) A high temperature controller shall operate with a minimum of three radiation pyrometers.

(B) (b) Control Modes.- The controllers shall be capable of manual, set point, and program operating modes which meet the performance requirements of Section 3.1.

(1) Manual Mode.- The manual mode shall be capable of at least 28 coarse power range changes to the full power rating, and of infinite control between these ranges.

(2) Setpoint Mode.- The setpoint mode shall be capable of automatically maintaining a predetermined power level.

(3) Programmer Mode.- The programmer mode shall be capable of continuously and automatically controlling a predetermined tamperature or power profile for each of three temperature ranges: low, middle, and high.

(B) (c) Overtemperature Limiting.- The deviation between the power and temperature profiles shall be limited to a predetermined span to prevent temperature overshoot.

3.3.1.12.4 Pressure Measurement and Instrumentation.- Gas pressure shall be measured at a minimum of two positions on the chamber and at appropriate positions on each vacuum pump. Cooling water pressure shall be measured.

(A) 3.3.1.12.5 Flow Rate Measurement and Instrumentation.- The flow rates of nitrogen and argon shall be measured and controllable.

3.3.1.12.6 Option No. 3, Inert Gas Pressure Control.- The furnace shell pressure shall be automatically controlled, and permanently recorded.

3.3.2 Selection of Specifications and Standards.- Standards and Specifications shall be selected by the contractor from paragraph 3.3.3.1.

3.3.3 Materials, Parts, and Processes.- Materials shall be new and shall conform to the requirements in referenced specifications.

3.3.3.1 Applicable Specifications.- The following material types shall be purchased with certification to the appropriate specifications.

(a) Aluminum	QQ-A-20
	QQ-A-250
(b) Copper	QQ-C-576

(c) Steel

MIL-S-6721
QQ-S-766
ANSI B 16.5-1961
ASTM A 193-68
ASTM A 194-68
ASTM A 240-67
ASTM A 276-67
ASTM A 312-64

3.3.3.2 Furnace System Component Material Selection.- Materials of construction shall be selected by the contractor and shall meet the following construction requirements.

3.3.3.2.1 Induction Heating Coil.- Materials of construction shall be resistant to corrosion from the furnace system environment and the coil shall have suitable electrical properties which prevent arcing during operation.

3.3.3.2.2 Susceptor.- Materials of construction considered by the contractor shall include bulk graphite and fibrous carbon. The latter proposed material may be procured from several sources including Rohr, Riverside, California; Hitco, Gardena, California; and Carbon Products Division, Union Carbide, Niagara Falls, New York.

3.3.3.2.3 Thermal Insulation.- Materials of construction shall be capable of providing the required useful life and maintainability in this specification. The contractor shall consider all candidate materials including lampblack, carbon blocks, granular carbon, and carbon and graphite felt.

3.3.3.2.4 Furnace Shell.- Materials of construction for the interior walls, port flanges, common size nuts and bolts, and nozzles shall be resistant to corrosion by the furnace system environment.

Section 4. QUALITY ASSURANCE

4.1 Supplier Responsibility.- The contractor shall prepare and submit with his proposal, a complete and concise description of a Quality Assurance Program the contractor proposes to utilize to assure compliance with the provisions of this specification.

4.2 Exceptions.- The contractor's Quality Assurance Program shall be based on compliance with SNPO-C-4 with the following exceptions.

(a) Part I - System Requirements.-

9.4	Evaluation
12.3	Sampling Plans
12.4	Statistical Quality Control Charts
14B.2	Monthly Quality Status Report
15.2	Audit Reports and Corrective Action

(A) (b) Appendix B - Quality Assurance Documentation Cross-Reference Index.-

		Referenced in Paragraph 22
2.	The Contractor shall submit the following for review:	
(d)	Results of Special Measuring and Test Equipment Evaluations	Part I,9.4
(e)	Special Sampling Plans; Application of Sampling	Part I, 12.3
(i)	Temporary Storage of End Items	Part II, 1.3.6
3.	The Contractor shall submit the following for information:	
(a)	Monthly Quality Status Report	Part I, 14B.2
(b)	Quarterly Summaries of Quality Program Performance Audits	Part I, 15.2

4.3 Special Acceptance Tests.-

4.3.1 Furnace Shell.- A leak rate and pressure test shall be performed on the furnace shell using the following methods:

(a) Evacuate the furnace shell to 50 microns pressure, having back-filled with helium three times.

(b) Seal-off the furnace shell and measure the leak rate.

(c) Maximum leak rate shall be 1 x 10^{-4} mm Hg per minute pressure, rise at 75 microns pressure.

(d) Pressurize furnace shell with helium at the contractor's design pressure.

(e) Seal-off the furnace shell, measure the leak rate, and record.

4.3.2 Induction Heating Coil.- A leak rate test shall be performed on the coil at the contractor's plant using the following method.

(a) Air pressure of 100 psig will be applied to the coil. Leaks will be detected by applying a soap solution, MIL-L-25567 on all joints. All leaks detected will be eliminated.

(b) Evacuate the coil to one micron absolute pressure or less.

(c) Place a plastic shroud over the coil and fill with helium.

(d) With a calibrated mass spectrometer leak detector, observe the leakage rate for five minutes.

(e) Maximum leak rate shall be 1 x 10^{-6} std cc/sec or less.

Section 6. NOTES

6.1 Facility Description.- The furnace will be installed by the contractor at ANSC Sacramento Facility as defined in drawing SPE-14-1-70 and utilizing the following additional information:

(a) A wall may be built in the pit to isolate the furnace area.

(b) This facility does experience electrical power outages at indeterminate periods of time.

(c) The emergency power generator, located in AGC Building 20005, may be used by the Contractor, manual operation activates the propane, 75KW at 480 volt, generator.

(A) (d) The main water supply is driven by pumps with an independent emergency backup power source.

6.2 Contractor Inspection.- ANSC and/or U. S. Government personnel reserve the right to inspect any of all of the work included in this order at the supplier's plant during fabrication at the contractor's or subcontractor's plant.

6.3 Drawings.- Two sets of detail drawings, descriptions, and a complete bill of materials will be submitted to the ANSC Engineering Department for approval prior to initiation of fabrication or procurement of any component of the furnace and its accessory equipment. Approval of components will not relieve the contractor of his obligation to supply a furnace and accessory equipment in strict conformance with the requirements of the application on

this specification. Three sets of assembly and detail drawings, wiring diagrams, and a complete bill of materials will be required prior to delivery and installation of the furnace and all accessory components. One set of reproducible drawings will be required upon ANSC acceptance of the furnace.

6.4 Operating Manuals.- Six complete sets of operating manuals describing operating, safety, maintenance procedures and parts list will be provided upon ANSC acceptance of the furnace.

6.5 Operating Performance Acceptance.- The contractor will provide a minimum of one operator and one engineer to initiate complete operation of the furnace and to demonstrate the required performance specifications to the satisfaction of ANSC.

6.6 Training.- During a maximum two-week period, and ANSC operator and engineer will be trained in the operation of the furnace.

6.7 Presentation.- A one-day presentation of the proposal in Cleveland, Ohio will be required of the bidder.

6.8 Option 2 - Low Temperature Control Capability.- This feature will be used at a maximum temperature of 850°C.

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TABLE 1

PHYSICAL PROPERTIES OF AG-CARB FIBROUS GRAPHITE

	TEMPERATURE, °F			
	RT	1000	2000	3000
Electrical Resistivity, ohm-cm x 10^{-4}	13-16	--	--	--
Thermal Conductivity, BTU/hr/ft^2/°F/ft				
Hoop	--	19	15	14
Radial	--	12	11	10
Thermal Expansion, in/in x 10^{-3}				
Hoop	--	1.6	3.2	5.5
Radial	--	2.6	5.3	7.8
Tensile Strength, ksi				
Hoop	11	--	12	13
Compressive Strength, ksi				
Radial	10	--	9	9
Flexure Strength, ksi				
Hoop	16-20	--	--	20-24
Density, gm/cc	1.45 $\pm$ 0.5	--	--	--

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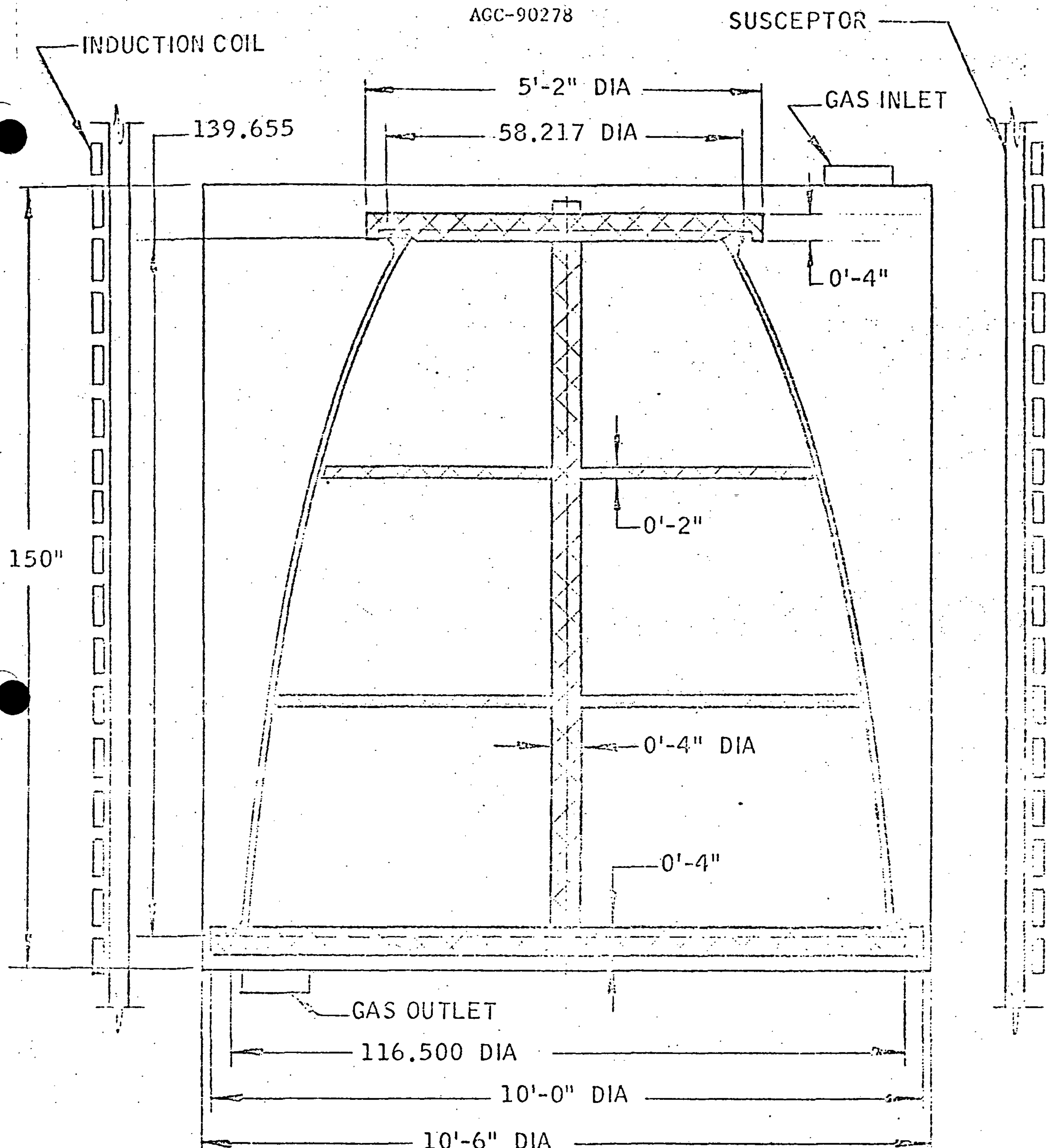
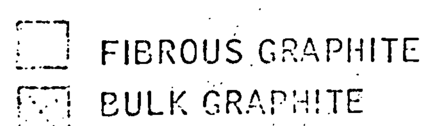


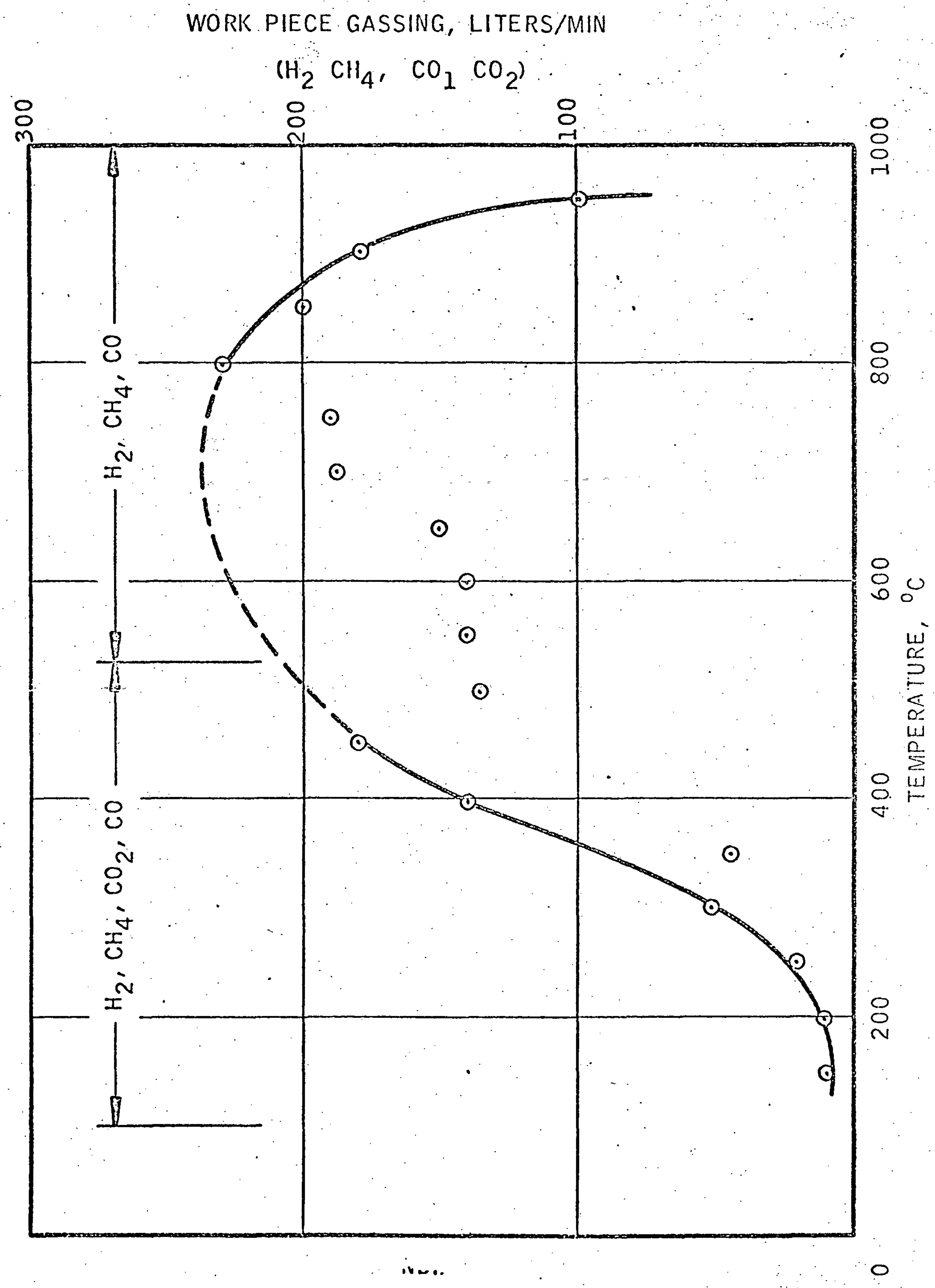
NOTE: WORK LOAD WEIGHTS

1. FIBROUS GRAPHITE 600 LBS
2. BULK GRAPHITE 6000 LBS
3. STEEL RETORT 3000 LBS (OPTIONAL)



INDUCTION FURNACE WORK LOAD SCHEMATIC

FIGURE 1



GAS RELEASE FROM WORK PIECE IN PROPOSED VACUUM INDUCTION FURNACE

FIGURE 2

APPENDIX C

ANSC INDUCTION FURNACE INSPECTION REPORT NO'S

503993, 503994, and 512330

AEROJET-GENERAL CORPORATION

INSPECTION REPORT

No 503993

SKETCH ATTACHED ☐

AGCS 0721-3 (REV. 6-68)

1. FACILITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH C/L	4. PART/MATERIAL NAME	ITEM S/N
2060-5	8 30 71	AGC-90278A		Induction Furnace	

5. PROJ/MODEL	6. Q CAT	7. W.O. NO.	8. INSPECTION CRITERIA	OTHER (EXPLAIN)
NERVA			☒ DWG. ☒ SPEC. ☐ I.I.	☒ Accept. Testo.

9. UNIT OF MEAS.	10. LOT SIZE	11. QTY. INSP.	12. QTY. NOT ACC.	13. CONTRACT NO.	14. S.O. NO.	36.
1	1	1	see below	SNP-1, Project 143		

16. BUY CO.	15. SUPPLIER NAME AND CODE	17. DISTR.	18. P.O./IWA NO.	37.
	Cragmet Div. of Cheston Corp.		N-00136	

30. GFP ☐ GFM ☐ CSI ☐	31. PREVIOUS REPORT NO.	32. TEST NUMBER	33. PRE TEST ☐ TEST ☐ POST TEST ☐	34. NEXT ASSY P/N	35. NEXT ASSY S/N	38.
	#512330					

19. DISCREPANCY OR NON-CONFORMANCE — 20. DISPOSITION/COMMENTS

CHAR/ITEM NO	CL. OF CHAR.	OCCUR	LIST IN ORDER: NO. PCS. - DWG/SPEC REQ - INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
			Per Purchase Order N-00136, AGC Spec. 90278A - the amendments to same, and the acceptance test plan consisting of Section I Mechanical Operation, Section II Electrical Operation, Section III Safety Interlocks and Section IV Performance. The following discrepancies and nonconformances are hereby noted:		

22. INITIATOR IDENTITY	DATE	INSP. SUPERVISOR	DATE	PROC./MFG. REPR.	DATE
[signature]	8-30-71				

23. ER/MR APPROVALS	ENG. REPR.	DATE	QC REPR.	CUST.	DATE
	Robert P. [signature]	8/71	[signature] 8-30-71		

24. REIN-SPECTION	QTY. ACC.	QTY. NOT ACC.	NEW I.R. NO.	FACILITY AND INSP. AREA	INSPECTION IDENTITY	DATE

25. ER/MR RESUBMITTAL DECISION	QTY. ACC.	QTY. NOT ACC.	QTY. OTHER (EXP.)	EXPLANATION OF OTHER	QC REPR.	DATE
	ENG. REPR.	DATE	CUST.	DATE		

26. CORRECTIVE ACTION

CAUSE OF DISCREPANCY	ACTION TO PREVENT RECURRENCE	EFFECTIVITY

27. RE-WORK	RESPONSIBILITY	QTY. RET.	QTY. SALVAGE	PROC./MFG. REPR.	DATE	QC REPR.	DATE

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

1. ...TY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2000-5	8 30 71	AGC-90278A			Induction Furnace		

☐ 19. DISCREPANCY OR NON-CON. OR ☐ 26. CAUSE OF DIS. ☐ 20. DISP./COMMENTS OR ☐ 26. ACT. TO PREV. RECUR.

CHAR/ ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER. NO: PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIN. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
1			Section I, Page 3, F. 4. Contractor did not demonstrate that the vacuum, mechanical pumps had the capabilities of pulling a vacuum to 10 microns.		1. Accept. The 10 micron valve is the ultimate minimum operating pressure for the vacuum pumps. The capability demonstrated was 17 microns, which is adequate to meet the requirements of the ANSC Spec No. AGC 90278A, Para 3.1.1.2.1.
2			Section I, Page 6, 6b, 8b, 9b, 10b & 11b. Measure water flow and record flow rate on Pumps Nos. 30-VP-1, 30-VP-2, 30-VP-3, 30-VP-4 & 30B-BL. Measure and record flow rate in middle, top and bottom furnace shells, not completed by contractor.		2. Accept. ANSC will make the required measurements.
3			Section II, Page 8, H. 2. d. Demonstrate that the silicon rectifier output is variable between 0 & 100 Vdc and has a maximum output of 100 amperes. Section II, Page 10, J. 3. through 3e. Demonstrate that the two pressure recorders Nos. 10-37 and pressure gauge No. 10-1 are calibrated to within 1% of full scale deflection.		3a. Accept. The silicon rectifier has a name plate rating of 100 Vdc. The control circuit requires a maximum 36 volt output. The voltage range of 0-36 volts was demonstrated, and is satisfactory to meet the performance requirements of the Specification. 3b. Preliminary Disposition - Supplier shall show calibration of the listed gauges. The Stokes McLeod gauge requires certification of calibration.

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

1. FACILITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2000-5	8 30 71	AGC-90278A			Induction Furnace		

☐ 19. DISCREPANCY OR NON-CON. CR ☐ 26. CAUSE OF DIS. | ☐ 20. DISP./COMMENTS CR. ☐ 30. ACT. TO PREV. RECUR.

CHAR/ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER. NO: PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
4			Section III, Page 13, B. 1. Contractor did not demonstrate that during vacuum pull down operation. The main vacuum valve closes automatically, trouble light turns on and horn sounds, when chamber rises above 20 ± Hg Vacuum.		4. Accept. The automatic valve closure was demonstrated at a pressure of 35 microns. This pressure valve is adequate to protect the vacuum pumping system from overpressure.
5			Section IV. Page 16. A. 1b. Contractor need to demonstrate that the furnace is controllable within ± 2% of any set point, set between 850°C & 2750°C. For this test controllability is to be 850°C ± 5°C, set point temperature.		5a. Accept. Controllability was demonstrated at 700°C. This temperature is acceptable in lieu of 850°C because it is a more difficult holding temperature for this equipment.
			Section IV, Page 17, 1g, 1g1, 1g3, 1h3, 1h5. Contractor has not completed this part of the temperature capability tests. The rate is established to decrease 15° ± 2°C per hour, between 2750 and 2680°C and 60° ± 6°C per hour between 2680° and 1800°C.		5b. Accept. The furnace temperature followed the control temperature rate demanded by the cam programer within the accuracy required. This demonstration showed that the furnace is controllable. Future operation will require more accurately cut CAMS to achieve the rates desired.
6			Section IV, Page 20, D. 2. Furnace cooling section is not complete. Contractor must demonstrate that cooling is sufficient and that the furnace shells, flanges and all attached fittings shall not exceed		6. Accept. The maximum shell temperature reached during the final run was 63°C on the top flange and 85°C on the bottom flange. These temperatur are acceptable because the furnace was

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

PAGE 4 OF ~~X~~ 9

1. FACILITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2000-5	8/30/71	AGC-90278A			Induction Furnace		

☐ 19. DISCREPANCY OR NON-CON. OR ☐ 25. CAUSE OF DIS. ☐ 20. DISP. COMMENTS OR ☐ 26. ACT. TO PREV. RECUR.

CHAR/ ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER. NO: PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
					losses which caused these skin temperatures.
7			Reference Section IV, Para. 1a, Page 15. Mechanical Vacuum Pumps. Contractor has operated all 4 pumps above the manufacturer's recommended amperage rating, and has at numerous times operated all 4 pumps without proper oil level, being evident in pump bases. Piping changes on exhaust system, installation of baffles in tees and oil equalizing piping system need drawing changes.		7. Preliminary Disposition. The mechanical pump motor amperes exceeded the manufacturer's rating. The furnace supplier shall certify that the manufacturer's warranty was not voided and warranty to one year from date of out-of-spec operation. Supplier shall make drawing revision, as described in Item 15A below.
8			Reference Section II, Para. J.5, Page 10. Duplex Cam Time Plotters - due to faulty or wrong cut cams on 10-23 Honeywell duplex temperature controllers, the controllers do not perform or control temperature decrease at 60°C per hour, as called out per Acceptance Test Procedure.		8. Accept. Furnace temperature followed temperature value demanded by cam controller within required accuracy. Future operation will require more accurately cut cams.

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AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

PAGE 5 OF ~~8~~ 9

1. FACILITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2000-5	8 30 71	AGC-90278A			Induction Furnace		

☐ 19. DISCREPANCY OR NON-CON. OR ☐ 26. CAUSE OF DIS. ☐ 20. DISP./COMMENTS OR ☐ 25. ACT. TO PREV. RECUR.

CHAR/ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER. NO. PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
9			Reference Section IV, Para. E. 2. Page 20 & Sec. 1, D1, Page 2. There are 23 documented areas of visual detectable deteriorations in the graphite felt insulation. Current condition warrants in order to maintain thermal insulation, additional felt must be added prior to any further use of said furnace.		9. Accept. Graphite felt was repaired and replaced satisfactorily by the supplier.
10			Reference (Section I, Para. b1, Page 2) Cragmet Tool No. 3086, "Workload Base & Measuring Tool". Contractor did not supply proper measuring tool for vertical alignment of the coils, susceptor or lower 42" work support rings.		10. Accept. Alternate methods of measurement were used to assure acceptable alignment.
11			Contractor did on numerous times overload the limitations on ANSC Power Sub-Station, passing the red line of amperes allowed.		11. Accept. Overload conditions were reviewed by ANSC Plant Engineering. The amount of overload was within the operating capability of the sub-station.
				11a	

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

[illegible] (4-67)

[illegible]ITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	[illegible]
[illegible]0-5	8 30 71	AGC-90278A			Induction Furnace		

CHAR/ ITEM NO	CLASS OF CHAR	OCCUR	LIST IN ORDER, NO. PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
12			Reference Section I, Para. (2), Page 5. Water Leaks. Contractor needs to replace/repair Crane Air Release Valve No. 676 on furnace spool weldment flange, #2. Center spool.		12. Accept. Supplier has repaired valve.
13			Reference Dwg. No. 3086-300-21 - Sight Port, Graphite parts detail. Contractor must align & adjust sight port tubes. Following all temperature furnace runs, the sight tubes were misaligned, making it impossible to obtain accurate temperature reading for subsequent runs.		13. Accept. Supplier has aligned sight port tubes. This condition will become less noticeable in future runs as settling of the graphite felt is completed.
14			~~[illegible]~~ ~~[illegible]~~ ~~[illegible]~~ Section (6), Page 7, 6.1 Inspection & Test Equipment. Contractor should certify that all inspection & testing equipment has been calibrated to an accuracy consistent with parameters and tolerances evaluated during said acceptance tests. IE. Normal water coolant pump gauge is pegged and not working.		14. Preliminary Disposition. Supplier shall provide certifications as noted. AMSC shall replace pump gauge.

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

PAGE 7 OF ~~8~~ 9

[illegible] (4-67)

1. [illegible] AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2[illegible]-5	8 30 71	AGC-90278A			Induction Furnace		

☐ 19. DISCREPANCY OR NON-CON. OR ☐ 26. CAUSE OF DIS. ☐ 20. DISP./COMMENTS OR ☐ 26. ACT. TO PREV. RECUR.

CHAR/ ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER. NO. PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
15			The following drawings must be upgraded by the contractor to show in detail changes in regards to the 'as built' configuration.		15. Preliminary Disposition. Supplier shall revise drawings to show the final as-built configuration.
			A. DWG. 3086-100-50 & 3086-600-20 Mechanical Pumps Vacuum, -Stokes. Installation of pump oil by-pass lines at ~~p~~ pumps base. Installation of Tee & Baffle in exhaust lines.		
			B. DWG. 3086-200-62, Rev. A, Bottom Felt Support Details. Installation of 28. SS304, 3/4" x 2'6" posts welded around bottom of inside furnace, "felt ~~k~~ insulation support."		
			C. DWG. 3086-100-20, Sheet 1. Argon System, Emergency. Contractor field decision to change direction and configuration of Argon Emergency Flow System Piping.		
			D. DWG. 3086-200-10, Graphite Felt Insulation. Contractor field decision to change method of felt installation, from lapped vertical installation to 6" & 7" rolled felt configuration.		
			E. DWG. 3086-600-30B, Furnace Top Lid, Water Coolant. Contractor change of design from blow-out disks to steel stand pipes at top lid and furnace bottom section.		

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

PAGE 8 OF 9

1. ACTIVITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2000-5	8 30 71	AGC-90278A		1	Induction Furnace		

CHAR/ ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER, NO: PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
15			F. DWG. 3086-200-41 (Detail A) Vacuum Chamber Weldment detail. Contractor field design change, installation of three air release valves at the flange area, of all three furnace spools - top flange area.		
			G: DWG. 3086-300-21, Sight Port Graphite Parts Detail. Contractor field decision to redesign and install a new configuration of top lid sight port.		
			H: DWG. 3086-600-30, Water Schematic & DWG. 3086-100-82, contractor field decision and redesign of larger coolant lines from furnace shells to drain.		
			I. DWG. 3086-200-10, Vacuum Furnace Assembly. Contractor field decision to install transite boarding around top of inside furnace, between induction coils and furnace wall.		
16			Section IV Page 16, A. 1d1. Contractor did not demonstrate that the furnace was automatically temperature controlled from 2600 to 2750°C per hour.	80	16. Accept. The specification does not require automatic temperature controllability between 2600°C and 2750°C. The supplier manually controlled temperature from corrected readings of 2600°C to 2695°C. This maximum temperature achieved is acceptable because it meets the temperature

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

PAGE 9 OF NO 9

1. [illegible] AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2000-5	8 30 71	AGC-90278A			Induction Furnace		

☐ 19. DISCREPANCY OR NON-CON: OR ☐ 26. CAUSE OF DIS. ☐ 20. DISP./COMMENTS OR ☐ [illegible]

CHAR/ ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER. NO: PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
17			Section IV, Page 16, 1el		controllability requirements of Spec
			Contractor did not demonstrate		90278A. Para 3.1.1.1.2 requires
			that the furnace temperature can be		controllability of +2% *(temperature
			manually adjusted to 2750°C,		correction method referenced below).
			maximum, and automatically		
			maintain this set point temperature		17. Accept. As stated above, the
			for 5 hours.		maximum temperature demonstrated met
					the requirements of the specification.
					Set point temperature control was
					within the temperature range of 2670°C
18			Section 1, Page 5, L 5		to 2695°C, which is acceptable.
			Contractor has not demonstrated		
			that the Baltimore air cooling		18. Accept. Supplier has reworked the
			tower operates without visible		cooling tower and has eliminated all
			water leakage.		water leakage.
19			Section IV, Page 20 1a, 1b & 2.		19. Accept. Anti-rust water
			Due to large rust formation in the		treatment is considered normal
			furnace shell inner walls and		maintenance, and will be provided by
			piping, rust inhibitor must be		AMSC during future furnace operation.
			added to the system. Contractor		
			has failed to demonstrate that		
			periodic maintenance is not re-		
			quired during any 14 day operating		
			cycle.		*Temperature Measurement Correction
					1. Quartz glass correction - National
					Bureau of Standards Technical
					Paper No. 170, "Pyrometric
					Practice".
				81	2. Target Emissivity -
					a. Kingery, W D, High Temperature
					Measurement [illegible]

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503993

PAGE 9a OF 9

1. FACILITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2000-5	8 30 71	AGC-90278A			Induction Furnace		

☐ 19. DISCREPANCY OR NON-CON. OR ☐ 25. CAUSE OF DIS. ☐ 20. DISP./COMMENTS OR ☐ 26. ACT. TO PREV. RECUR.

CHAR/ ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER. NO. PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
					b. Rudy, E, Pirini Furnace for
					the Precise Determination of the
					Melting Temperature of Refractory
					Substances.
					3. Hot Zone and Target Temperature
					Difference - Memo N8110:M1745,
					dtd 8 September 1971, Temperature
					Measurement in Inert Induction
					Furnace.
				82	

AEROJET-GENERAL CORPORATION

INSPECTION REPORT

Nº 503994

SKETCH ATTACHED ☐

(REV. 6-68)

PAGE 1 OF 2

1. FAC. AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH C/L	4. PART/MATERIAL NAME	ITEM S/N
2000-5	9 14 71	AGC 90278A		Induction Furnace	

5. PROJ/MODEL	6. Q CAL	7. W.O. NO.	8. INSPECTION CRITERIA	OTHER (EXPLAIN)
NERVA			☒ DWG. ☒ SPEC. ☐ I.I.	☒ Accept Test NO.

9. UNIT OF MEAS.	10. LOT SIZE	11. QTY. INSP.	12. QTY. NOT ACC.	13. CONTRACT NO.	14. S.O. NO.	36.
1	1	1	See below	SNP-1, Project 143		

15. SUP CO.	16. SUPPLIER NAME AND CODE	17. DISTR.	18. P.O./IWA NO.	37.
	Cragmet Div. of Cheston Corp.		N-00136	

20. GFP ☐ GFM ☐ GSI ☐	21. PREVIOUS REPORT NO.	22. TEST NUMBER	33. PRE TEST ☐ TEST ☐ POST TEST ☐	34. NEXT ASSY P/N	35. NEXT ASSY S/N	38.
	503993					

19. DISCREPANCY OR NON-CONFORMANCE	20. DISPOSITION/COMMENTS
LIST IN ORDER: NO. PCS. - DWG/SPEC REQ - INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION / REVIEW DECISIONS ☐ ER ☐ MR
During the operation of painting the Induction Furnace, the painting crews broke loose the Crane #676 Air bleed valve to the middle furnace spool weldment, (Ref. DWG. 3086-200-41, Detail A.) Visual inspection reveals that the installation of the 1/2" N.P.T. Nipple which supports the valve was of poor workmanship. The nipple was supported by only three threads and the tapped 1/2" threaded hole was irregular with the threads being shallow. It should also be noted that this particular furnace	Accept. ANSC shall reinstall the air bleed valve and fill with water.

22. INITIATOR IDENTITY	DATE	INSP. SUPERVISOR	DATE	PROC./MFG. REPR.	DATE
[signature]	9-14-71			[signature]	[illegible]

23. ER/MR APPROVALS	ENG. REPR.	DATE	QC REPR.	CUST.	DATE
	[signature]	[illegible]	[signature]		

24. REIN-SPECTION	QTY. ACC.	QTY. NOT ACC.	NEW I.R. NO.	FACILITY AND INSP. AREA	INSPECTION IDENTITY	DATE

25. ER/MR RESUBMITTAL DECISION	QTY. ACC.	QTY. NOT ACC.	QTY. OTHER (EXP.)	EXPLANATION OF OTHER	QC REPR.	DATE
	ENG. REPR.	DATE	CUST.	DATE		

26. CORRECTIVE ACTION

CAUSE OF DISCREPANCY	ACTION TO PREVENT RECURRENCE	EFFECTIVITY

83

27. REJECTED MATERIAL DISPOSITION	RESPONSIBILITY	QTY. RTS	QTY. SALVAGE	PROC./MFG. REPR.	DATE	QC REPR.	DATE
	☐ AGC ☐ SUPPLIER	—					

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 503994

PAGE 2 OF 2

1. FACILITY AND INSP. AREA	2. MO.	DAY	YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2000-5	9	14	71	AGC 90278A			Induction Furnace		

☐ 19. DISCREPANCY OR NON-CON. OR ☐ 28. CAUSE OF DIS. | ☐ 20. DISP./COMMENTS OR ☐ 29. ACT. TO PREV. RECUR.

CHAR/ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER, NO: PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
			shell has lost a considerable amount		
			of specially treated water, all from		
			the top spool weldment and to the		
			top level of the center spool. Top		
			and center spools are linked		
			together by a common water		
			coolant line.		

COMPANY

INSPECTION REPORT

№ 512330

SKETCH ATTACHED ☐

0721-3 (REV 1/71)

1. FACILITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH C/L	4. PART/MATERIAL NAME	ITEM S/N
2005	6 23 71	AGC-90278A		Induction Furnace	

5. PROJ/MODEL	6. G CAL	7. W.O. NO.	8. INSPECTION CRITERIA
NERVA			☐ DWG. ☐ SPEC. ☐ I.I. OTHER (EXPLAIN) ☒ Purchase Order.

9. UNIT OF MEAS.	10. LOT SIZE	11. QTY. INSP.	12. QTY. NOT ACC.	13. CONTRACT NO.	14. S.O. NO.
1	1	1	See Below	SNP-1 Project 143	

15. BUY CO.	16. SUPPLIER NAME AND CODE	17. DISTR.	18. P.O./IWA NO.
	Cragmet		N-00136

30. GFP ☐ GFM ☐ SSI ☐	31. PREVIOUS REPORT NO.	32. TEST NUMBER	33. PRE TEST ☐ TEST ☐ POST TEST ☐	34. NEXT ASSY P/N	35. NEXT ASSY S/N

CHAR/ITEM NO.	CL. OF CHAR.	OCCUR	19. DISCREPANCY OR NON-CONFORMANCE — LIST IN ORDER: NO. PCS - DWG/SPEC REQ - INSP. RES - ITEM IDENT.	21. PRELIM. DECISION	20. DISPOSITION/COMMENTS — REVIEW DECISIONS ☐ ER ☐ RR
I			Per Purchase Order, Paragraph 8		
			Furnace System startup.		
			The Seller has completed a preliminary		
			system check as required by sub		
			paragraph 1 in accordance with the		
			Sellers submitted activation and		
			acceptance plan. Section 1 Activate		
			Water System and Section 2 Activate		
			Pumping System. The following con-		
			ditions are reported:		
			1) The preliminary system check was		1. Accept. Supplier's plan was
			run without ANSC approval of the		rejected and supplier was directed to
			Seller's plan.		meet requirements of ANSC Acceptance
					Plan.

22. INITIATOR IDENTITY	DATE	INSP. SUPERVISOR	DATE	PROC./MFG. REPR.	DATE
[signature]	6-23-71	[signature]	6/23/71		

23. ER/RR APPROVALS	ENG. REPR.	DATE	QC REPR.	DATE	CUST.	DATE
	[signature]	10/14/71	[signature]	10-27-71		

24. REIN-SPECTION	QTY. ACC.	QTY. NOT ACC.	NEW I.R. NO.	FACILITY AND INSP. AREA	INSPECTOR IDENTITY	DATE

25. ER/RR RESUBMITTAL DECISION	QTY. ACC.	QTY. NOT ACC.	QTY. OTHER (EXP.)	EXPLANATION OF OTHER	QC REPR.	DATE
	ENG. REPR.	DATE	CUST.	DATE		

26. CORRECTIVE ACTION

CAUSE OF DISCREPANCY	ACTION TO PREVENT RECURRENCE	EFFECTIVITY

RESPONSIBILITY	QTY. RTS.	QTY. SALVAGE	PROC./MFG. REPR.	DATE	QC REPR.	DATE

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 512330

0721-4 (4-67)

1. FACILITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2005	5 23 71	AGC 90278A					[illegible]

☐ 19. DISCREPANCY OR NON-CON. OR ☐ 25. CAUSE OF DIS. ☐ 20. DISP./COMMENTS OR ☐ 26. ACT. TO PREV. RECUR.

CHAR/ ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER. NO: PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
			2) The following unplanned events and actions are reported for record and evaluation: During the activation of the pumping system while pumping down the chamber the oil levels in vacuum pump 1 & 2 3 & 4 were unstable, resulting in oil flowing from one pump to another thru the venting system allowing one or the other pump's oil supply to become depleted to below recommended oil level. The Seller attributed the condition to back pressure at the 15 foot level manifold, and the need for baffles in the T joint connecting pumps and vent system.		2. Accept. The oil transfer from one pump to the other was corrected by connecting a common line between the oil sumps of each pump, so that the oil would seek a common level. Baffles were placed at the pump T-joint inlet to reduce pump oil transfer between sister pumps.
			3) Supplier fabricated and installed baffles in the T section which is not in accordance with the Seller's drawing as approved by ANSC. The Seller states that the back pressure is caused by ANSC's vent system and recommends modification .		3. Preliminary Acceptance. The baffles were installed upon the recommendation of the pump manufacturer to help prevent oil transfer between sister pumps. This rework is acceptable. The supplier will revise Dwg. No. 3086-100-50 and 3086-600-20 accordingly. The ANSC vent system was enlarged as recommended by the pump manufacturer.
			4) The pit is in an unsafe condition as a result of oil being spilled during the Sellers draining and refilling of the vacuum pump oil system. The bottom of the pit is covered with oil, stairways and platforms have been made slick with oil, as a result of tracking, oil was washed down the drain which is in violation of safety regulations, the area has an excessive amount of raw		4. Accept. ANSC had the pit area cleaned. Safety declared the area acceptable.

AEROJET-GENERAL CORPORATION

INSPECTION REPORT - Cont. Sheet

NO. 512330

AGCS ...-4 (4-67)

1. FACILITY AND INSP. AREA	2. MO. DAY YR.	3. PART NO.	DASH	C/L	5. PART S/N	SHOP ORDER NO.	PROGRAM
2005	6 23 71	AGC 90278A					NERVA

☐ 19. DISCREPANCY OR NON-CON. OR ☐ 25. CAUSE OF DIS. | ☐ 20. DISP./COMMENTS OR ☐ 26. ACT. TO PREV. RECUR.

CHAR/ITEM NO	CLAS OF CHAR	OCCUR	LIST IN ORDER, NO: PCS. - DWG/SPEC - REQ INSP. RES. - ITEM IDENT.	21. PRELIM. DECISION	REVIEW DECISIONS ☐ ER ☐ MR
			the pit area.		
II			SECTION 3, FIELD SERVICES:		Accept. The supplier was informed
			On 6-23-71 the Seller was preparing		of the need for additional personnel
			to perform operations initially to		and met the requirement to provide
			activate the pumps with only one engineer		two operating personnel.
			available. The purchase order requires		
			the Seller's services of one operator		
			and one engineer to initiate complete		
			operation of the furnace, etc.......		

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<u>APPENDIX D</u>

THERMAL ANALYSIS

FOR

INDUCTION FURNACE

TEMPERATURE MEASUREMENT CORRECTIONS

C. 2

AEROJET NUCLEAR SYSTEMS COMPANY

SACRAMENTO, CALIFORNIA

TO:	O. J. Demuth	28 September 1971 DTB:jm N8110:M1746
FROM:	D. T. Buchanan	
SUBJECT:	Temperature Measurement in Inert Induction Furnace (Including Detailed Target Analysis)	
DISTRIBUTION:	L. B. Claassen, C. M. Kawashige, R. P. Radtke, K. Sato, L. A. Shurley, W. R. Thompson, P. P. Ventura, J. J. Williams	

REFERENCES:

(a) Memo N8110:M1733, D. T. Buchanan to O. J. Demuth, Subject: "Temperature Measurement in Inert Induction Furnace", dated 25 August 1971

(b) A. R. Ubbelohde et al., "Graphite and Its Crystal Compounds", Clarendon Press, Oxford, 1960

(c) Union Carbide Form CCP-3713 "Effective Thermal Conductivity for Carbon & Graphite Felts", Page 8, dated 9-30-1970

(d) Cragmet Corporation Drawing 3080-300-20, "Sight Port Assembly with Thermocouple Unit", dated 3-19-1971

INTRODUCTION:

This memorandum supersedes Reference (a) and replaces it in its entirety.

SUMMARY:

A thermal analysis was conducted to estimate the effect of the specific load on susceptor temperature within the induction furnace for testing the graphite skirt extension. A one-dimensional analysis indicated that the load consisting of three 2200 lb "candle sticks" will track the susceptor temperature within 2°F at furnace temperatures in excess of 3800°F with a constant susceptor power input of 1500 KW. Therefore, it was concluded that there is no effect of load on susceptor temperature at a given input power near steady-state conditions.

A simple thermal analysis was conducted of the target device which penetrates the furnace insulation and is viewed by a pyrometer. The analysis predicts target temperatures approximately 170 to 185°F below the susceptor and load temperatures.

ANALYSES:

A one-dimensional thermal model of the furnace was coded for the E12901 "Thermal Analyzer" program. The load was input as a single capacitance node with thermal radiation exchange with the susceptor and inner insulation surface. The capacitance of the load was based on a weight of 6600 lbs of graphite with temperature-dependent thermal capacitance as taken from Reference (b). The thermal radiation exchange between the susceptor and the load was based on the surface area of the three 16 in. diameter "candle sticks", each 113 in. high with a shape factor of 1.0 from the susceptor to the load. The susceptor was also input as a single node with a mass of 8000 lbs with its thermal capacitance from Reference (b).

Because of the wide variation in temperature through the insulation a single node approach would have produced a gross error in the thermal capacitance. Therefore, six capacitance nodes representing 333 lbs of insulation each were input with an additional outer surface node held constant at 200°F. This approach presented a problem in selecting the correct thermal conductivity because the data provided in Reference (c) is mean conductivity based on the hot side temperature. Therefore, the conductivity from Reference (c) was adjusted percentage wise to give the specified steady state susceptor and load temperature. This method assured that the total heat loss from the furnace at the specified temperature of 4930°F (2720°C) is approximately correct.

A twelve hour transient thermal analysis was then run with a susceptor heating rate of 1.5 MW. This heating rate accounts for losses in the coil; it is assumed that approximately 1.75 MW are required at the coil to produce a 1.5 MW heat rate at the susceptor. This transient analysis indicated that the load will follow the susceptor temperature within 2°F for temperatures above 3800°F where the temperature rise rate is approximately 250°F/hr.

A simple thermal heat balance of the target used to measure the furnace temperature with a pyrometer was conducted. It was assumed that the target tube as shown on Reference (d) protrudes approximately 3-1/2 inches beyond the

inner insulation surface. The net radiation exchange between the furnace and the outer surface area of that portion of the target which protrudes into the furnace was balanced with heat losses due to stem conduction and thermal radiation to the 200°F sink outside of the insulation. This energy balance was developed as follows:

$$Q_{in} = A \alpha \sigma \left(T_f^4 - T_1^4\right) \qquad (1)$$

where
Q_{in} = net heat received by target, Btu/sec
A = outer surface of target tube which extends into furnace, in.^{2}
α = absorptivity of target tube (0.95), dimensionless
σ = Stefan-Boltzmann constant, Btu/in.^{2}-sec-°R^4
T_f = furnace temperature (5390°R)
T_1 = target temperature, °R

Similarly:

$$Q_{out} = A_T \mathcal{E}_e \sigma \left(T_1^4 - 200^4\right) + \left(T_1 - 200\right) A_c k/x \qquad (2)$$

where
Q_{out} = heat loss from target, Btu/sec
A_T = target area, in.^{2}
$\mathcal{E}_e$ = effective emissivity of target, dimensionless
A_c = cross sectional area of graphite material of target tube/in.^{2}
k = conductivity of graphite, Btu/in.-sec-°R
x = thickness of insulation, in.

Since the heat loss must equal the net radiation absorbed from the furnace by the target tube, Equation (1) was set equal to Equation (2)

$$A \alpha \sigma \left(5390^4 - T_1^4\right) = A_T \epsilon_c \sigma \left(T_1^4 - 200^4\right) + \left(T_1 - 200\right) A_c k/x$$

and solved for T_1.

The inner and outer surfaces of the insulation through which the target tube passes were assumed to be 4930°F (5390°R) and 200°F respectively. It was therefore estimated that the heat exchange between the target tube and insulation will be minimal and could be neglected considering the preliminary nature of this analysis.

Assuming effective emissivities of .95 and .85, the target temperature errors ($T_F - T_T$) were estimated to be 170 and 185°F respectively using the above expression.

CONCLUSIONS:

The above analysis was based on an assumed maximum obtainable furnace temperature of 2720°C and was not intended to determine the steady-state furnace temperature. The transient analysis was conducted to determine the temperature lag of the load surface compared with the susceptor, and to determine if this lag could significantly influence susceptor temperature.

It was speculated that because of the lower surface-to-mass ratio of the "candle sticks" compared to the prototype skirt extension, a load temperature lag and therefore an effect of load on the susceptor temperature might be introduced; this analysis shows that such is not the case. As the load and the susceptor are at essentially the same temperature above 2800°F (1538°C) there should be no error introduced from this source, and the use of candle sticks in place of the prototype skirt extension should have minimal effect on the furnace performance.

The energy radiated from the inner surface area of the target tube will exit through the open end to the 200°F sink or strike the inner surface of the tube. That radiant energy striking the inner surface will either be reflected, re-radiated or conducted to the 200°F sink. Therefore, for the purpose of radiation calculations, the approximation was made that the tube appears as a disk having the I.D. of the tube, and located at the outer end of the tube.

This phenomenon results in the "equivalent" disk having an effective emissivity approaching unity (fairly independent of the tube length or material emissivity)[1]. However, if the diameter of the tube is increased, the ratio of emitting target area to the area of the tube receiving radiation from the furnace

1. E. M. Sparrow, Radiation Heat Transfer, Brooks/Cole Co., Belmont, Calif. 1966, p. 164

will be increased, resulting in a greater target temperature error.

The analysis on the target tube indicates that the target, due to heat losses through stem conduction and thermal radiation, is approximately 175°F lower than the load and susceptor temperature. It is recommended that a more accurate thermal analysis of the target be conducted to allow for a correction in the measurement or that a more accurate method of temperature measurement be devised.

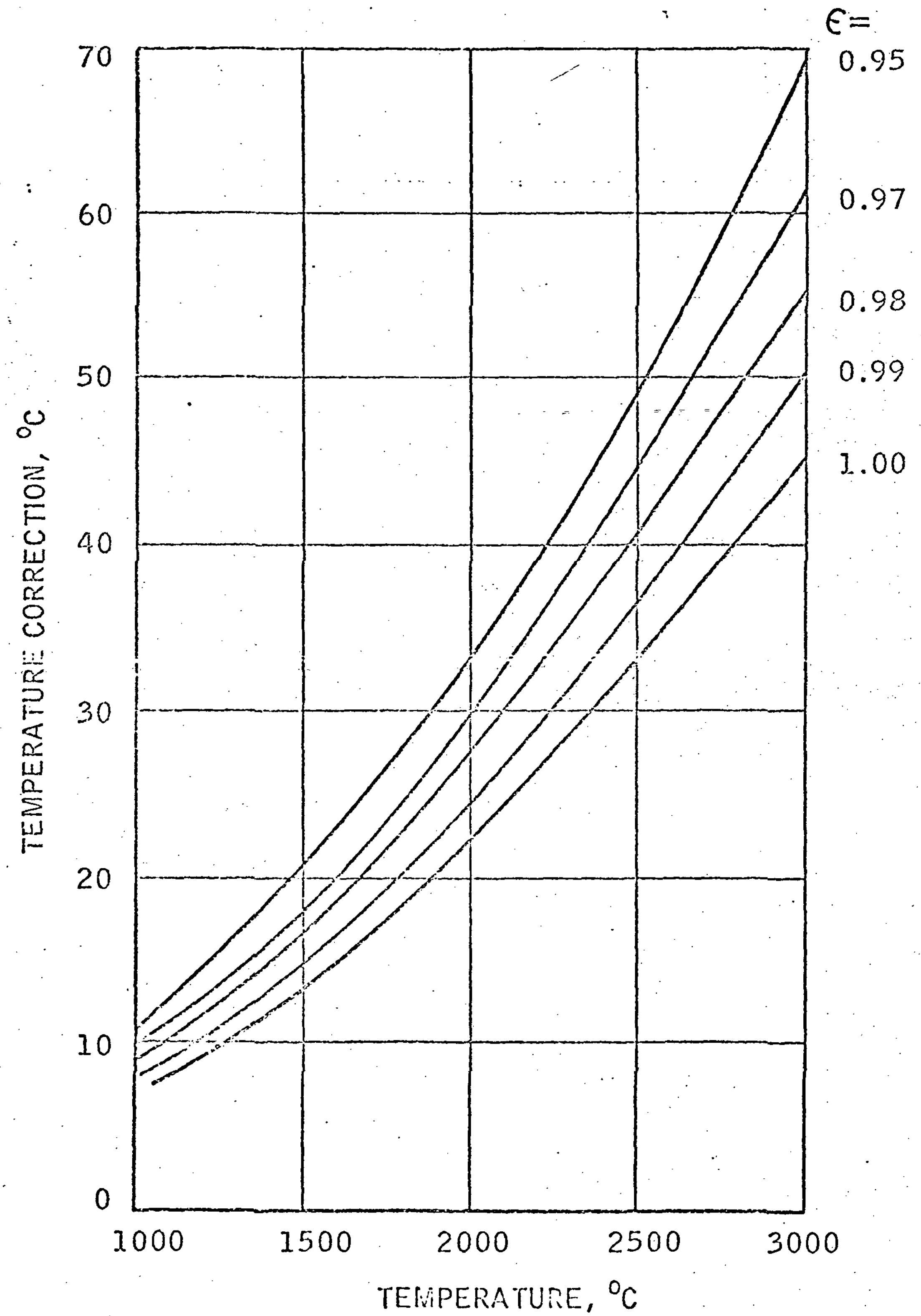
D. T. Buchanan
Thermophysics Section
Engineering Staff Department

APPENDIX E

TEMPERATURE CORRECTION

FOR

EMISSIVITY AND ABSORPTION OF QUARTZ GLASS



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1.00
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40
30
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10
0
1000
1500
2000
2500
3000
TEMPERATURE CORRECTION, °C
TEMPERATURE, °C